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# Selecting an Information System to Support a Business Process – a Case Study on Material and Production Forecasting

Master's Thesis

Espoo, October 6, 2014

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**Abstract**

A manufacturing company needs to predict the demand for essential components. This is because suppliers need a forecast to buy components, reserve capacity and manage inventories, whereas the manufacturing company needs a forecast to buy components with a long lead time in advance, to optimize its production capacity and to make investment decisions.

The main objective of this thesis is to determine how to generate a material and production forecast for a Nordic manufacturing company using software systems. Two research methods are used. An action research consists of interviewing seven critical stakeholders and the application of statistical forecasting methods into practice. A literature review consists of searching articles in four academic databases and analyzing them.

It was found, that a modified version of the typical five-step sales and operations planning process can be used to generate a sufficiently accurate material and production forecast for the case company. Business requirements for the material and production forecasting systems can be derived by analyzing the business process. User requirements for the system can be derived by interviewing critical stakeholders. The system can be selected using a modified version of the procurement-oriented requirements engineering (PORE). The two commercially available systems under study appear to satisfactorily meet the business and user requirements.

The results imply that the three-step model used in this thesis to select an information system is applicable to other business processes as well. In the first step the business process is defined. In the second step the user requirements are defined. In the third step an information systems is selected based on the requirements derived in the first two steps. This model appears to result in selecting a system that truly supports the business process.

**Keywords** business process development, demand management, information systems procurement, requirements engineering

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**Tiivistelmä**

Tuotantoyrityksen tulee voida ennakoida keskeisten komponenttien kysyntä. Toimittajat tarvitsevat tällaisen ennusteen ostaessaan komponentteja, varatessaan kapasiteettia ja hallitessaan varastoja. Tuotantoyritys tarvitsee tällaisen ennusteen ostaessaan pitkän läpimenoajan komponentteja etukäteen, optimoidessaan tuotantokapasiteettia ja tehdessään investointipäätöksiä.

Tämän työn tarkoituksena on selvittää, kuinka pohjoismaiselle tuotantoyritykselle voidaan tuottaa materiaali- ja tuotantoennuste. Tähän käytetään kahta tutkimusmenetelmää. Toimintatutkimus koostuu seitsemän kriittisen sidosryhmän edustajan haastatteluista ja tilastollisten ennustemenetelmien soveltamisesta käytäntöön. Kirjallisuuskatsaus koostuu artikkeleiden etsimisestä neljästä akateemisesta tietokannasta ja niiden analyysistä.

Muokattu versio tyypillisestä viisiportaisesta sales and operations planning -prosessista tuottaa riittävän tarkan materiaali- ja tuotantoennusteen kohdeyritykselle. Liiketoimintavaatimukset materiaali- ja tuotantoennustejärjestelmälle voidaan johtaa analysoimalla liiketoimintaprosessia. Käyttäjävaatimukset voidaan johtaa haastattelemalla keskeisten sidosryhmien edustajat. Järjestelmä voidaan valita käyttämällä muokattua versiota hankintasuuntautuneesta vaatimusmäärittelystä. Tarkastellut kaksi kaupallisesti saatavilla olevaa järjestelmää näyttävät täyttävän liiketoiminta- ja käyttäjävaatimukset hyvin.

Tulokset viittaavat siihen, että tässä opinnäytetyössä käytetty kolmivaiheinen tietojärjestelmän valintamalli on sovellettavissa myös muihin liiketoimintaprosesseihin. Ensimmäisessä vaiheessa määritellään liiketoimintaprosessi. Toisessa vaiheessa määritellään käyttäjävaatimukset. Kolmannessa vaiheessa valitaan tietojärjestelmä kahdessa ensimmäisessä vaiheessa määriteltyjen vaatimusten perusteella. Tämä malli näyttäisi johtavan sellaisen järjestelmän valintaan, joka aidosti tukee liiketoimintaprosessia.

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## Abbreviations

| | |
|---|---|
| COTS | Commercial Off-The-Shelf |
| CS | Case Study |
| DSB | Demand Supply Balancing |
| ERP | Enterprise Resource Planning |
| IS | Information System |
| LCM | Life Cycle Management |
| LR | Literature Review |
| P&P | Planning and Purchasing |
| PORE | Procurement-Oriented Requirements Engineering |
| RE | Requirements Engineering |
| RQ | Research Question |
| S&OP | Sales and Operations Planning |
| SKU | Stock Keeping Unit |
| SLR | Systematic Literature Review |
| SMAPE | Symmetric Mean Absolute Percentage Error |
| VMI | Vendor Managed Inventory |

# 1 Introduction

## 1.1 Motivation and background

A manufacturing company needs to predict demand for essential components in advance. Suppliers need this information to buy components, reserve capacity and manage inventories. The manufacturing company needs this information to buy components with a long lead time in advance, to optimize its production capacity and to make investment decisions. The demand can be predicted using judgmental methods, statistical methods or a combination of these two. When judgmental methods are used, the forecast is provided by humans. When statistical methods are used, the forecast is calculated using computers.

Wallace (2006) presents a sales and operations planning process (S&OP), which is based on judgmental methods. The process is divided into five steps. Thomé et al. (2012) describe S&OP as a tool that unites different business plans into one integrated set of plans. According to them, it has two purposes. First, it tries to balance supply and demand. Second, it tries to build bridges between the business or strategic plan and the operational plan of the firm. Chase (1997) presents statistical methods that can be used in forecasting. They include naive method, moving average, exponential smoothing, decomposition and Box–Jenkins.

## 1.2 Research problem and questions

The main objective of this thesis is to determine how to generate a material and production forecast for a Nordic manufacturing company using software systems.

The research problem is divided into the following research questions:

1. What process can provide an accurate enough material and production forecast for the case company?
2. What are the requirements of a material and production forecasting system in the case company?
3. How to select a material and production forecasting system for the case company?

The interrelationship between the research questions is presented in Figure 1. The requirements derived in the first two research questions are used to select an information system (IS) in the third research question. The information about the business process is utilized when the requirements are derived.

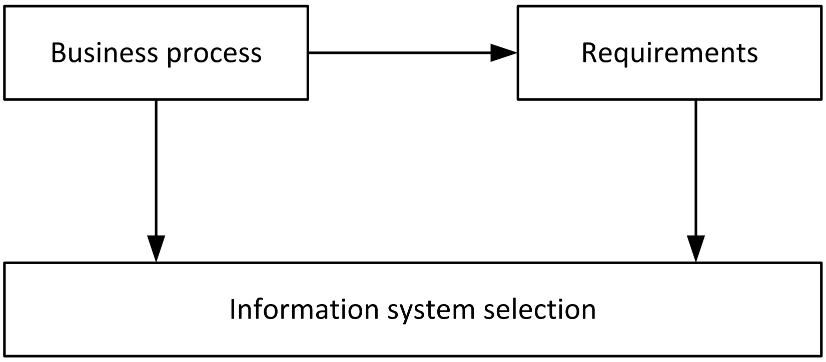


**Figure 1: The interrelationship between the research questions**

## 1.3 Structure of the thesis

This thesis is organized into nine chapters. Chapter 1 defines the research questions of the thesis. Chapter 2 discusses the research methods used to answer the research questions. Chapters 3 and 4 contain the results of the literature review. Chapters 5 to 7 contain the results of the empirical study. Chapter 8 summarizes the answers to the research questions and evaluates their validity. Chapter 9 concludes with the findings of the thesis regarding the research problem. The structure is visualized in Figure 2.

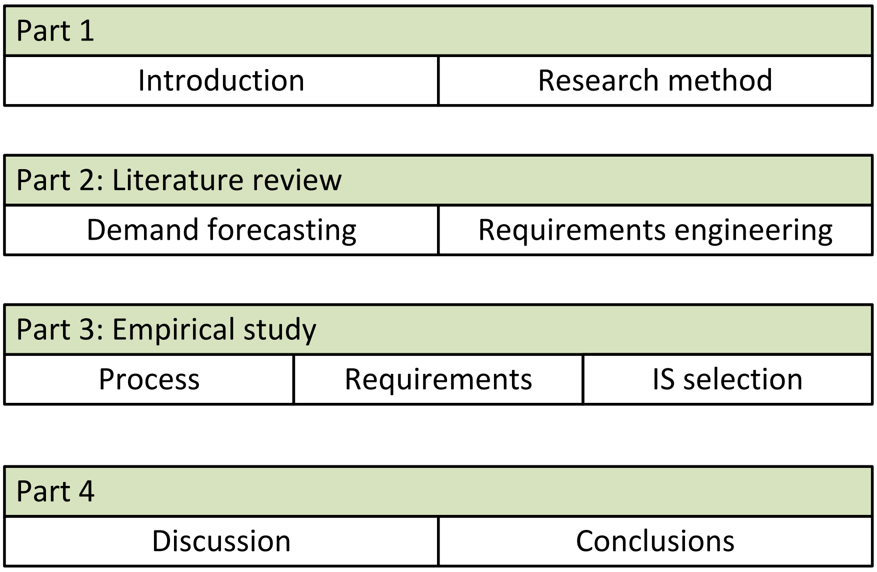


**Figure 2: Structure of the thesis**

# 2 Research method

## 2.1 Overview of the methods used

The thesis has two research methods. The primary method is an empirical study. The empirical study consists of interviews and applying statistical methods to practice. The secondary method is a literature review. The division of research questions (RQ) into literature review sub-objectives (LR) and case study sub-objectives (CS) is presented in Table 1.

**Table 1: Sub-objectives and search strings**

| RQ | Sub-objective and search query |
|---|---|
| 1 | LR1. What S&OP maturity level frameworks exist?<br>• Elsevier Science Direct: “sales and operations planning”<br>• articles Thomé et al. (2012) had cited |
| 1 | LR2. How to generate a material and production forecast using judgmental methods?<br>• articles Thomé et al. (2012) had cited |
| 1 | LR3. How to generate a material and production forecast using statistical methods?<br>• Elsevier Science Direct: “demand forecasting” AND “quantitative model”<br>• Elsevier Science Direct: “supply chain management” AND “automatic forecasting” |
| 2 | LR4. How to classify stakeholders?<br>• IEEE/IEE Electronic Library: “.QT.requirements engineering.QT. stakeholders<br>• Web of Science – WoS (ISI): articles citing the papers found so far |
| 2 | LR5. How to define requirements?<br>• articles Kauppinen (2005) had cited |
| 3 | LR6. What processes support selecting commercial of-the-self product?<br>• articles Ottka (2014) had cited |
| 1 | CS1. What is the maturity level of the current S&OP implementation in the case company? |
| 1 | CS2. What should be the S&OP process in the timeframe of next two years? |
| 2 | CS3. What is the requirements specification of a material and production forecasting system? |
| 3 | CS4. How to use the requirements specification for selecting a commercially available system? |

## 2.2 Literature review

### 2.2.1 Demand forecasting

The literature review on sales and operations planning consists of three steps (LR1–LR3). First, I wanted to find out what S&OP maturity level frameworks exist. I used "Elsevier Science Direct" to find a pre-existing SLR by Thomé et al. (2012). This study was used to identify relevant primary studies. Second, I wanted to find out how to generate a material and production forecast using judgmental methods. I used the SLR identified in the previous step to identify relevant primary studies. Third, I wanted to find out how to generate a material and production forecast using statistical methods. I used "Elsevier Science Direct" to identify two primary studies relating to the topic.

### 2.2.2 Requirements engineering

The literature review on requirements engineering consists of three steps (LR4–LR6). First, I wanted to find out how to classify stakeholders. I used "IEEE/IEE Electronic Library". I found 321 articles, which were sorted based on their relevance. I went through 100 most relevant and selected 13 based on topic and abstract. Skimming through methods and results reduced the number of articles to 6. Reading the results fully reduced the number of articles to 3. In addition to this, one article was added because it was known to relate to the topic.

Furthermore, I used "Web of Science" to find the articles citing the papers found so far. The method is called forward snowballing and it leads to more recent publications on the same subject. I selected 5 articles based on topic and abstract. Skimming though methods and results reduced the number of articles to 3. Reading the results fully reduced the number of articles to 2.

Second, I wanted to find out how to define requirements. I used academic databases to find out articles Kauppinen (2005) had cited. The method is called backward snowballing. Third, I wanted to find out how to select a commercial off-the-self product using a list of requirements. I used academic databases to find out articles Ottka (2014) had cited.

## 2.3 Case study

### 2.3.1 Case company

The case company is a manufacturer of high tech electronics. The company's product portfolio is wide compared to the annual volume it ships. This increases requirements for the forecasting tool because the system has to manage a large number of configurations. The manufactured products are mass-customized or individually tailored. They are assembled to order, in other words they are not built until a confirmed order is received.

The company has less than 2000 employees. The organization is divided into two business areas which are called in this thesis equipment business area and system business area. The equipment business area is characterized by product business. The system business area is characterized by project business, although it has some product business as well.

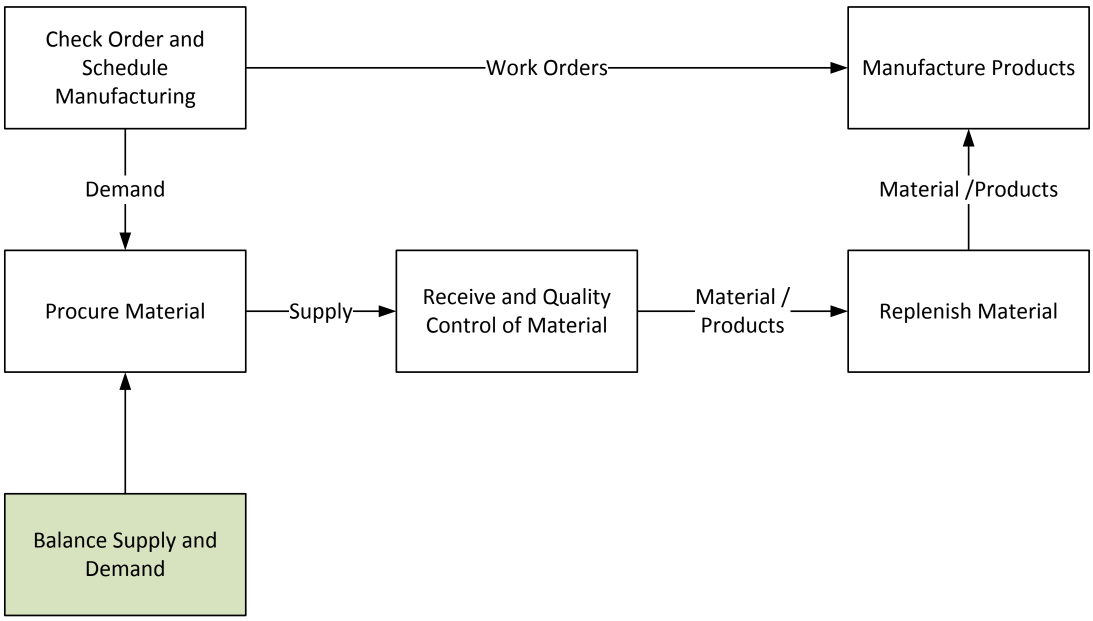


**Figure 3: A part of product sales to delivery process (Case company 2014)**

The current demand management process is called Demand Supply Balancing. It is a part of the product sales to delivery process as presented in Figure 3. The purpose of “Check Order and Schedule Manufacturing” is to check new order lines for order errors and schedule order backlog with material and capacity constraints. The purpose of “Procure Material” is to describe how material is purchased with different methods. The purpose of “Balance Supply and Demand” is to ensure the flow of forecast through suppliers to production planning, purchasing and manufacturing. The purpose of “Receive and Quality Control of Material” is to receive, check and distribute material to the defined location. The purpose of “Replenish Material” is to describe how internal logistics is replenishing material between inventories and teams. The purpose of “Manufacture Products” is to describe the manufacturing process in different locations of the case company.

The forecast is generated using an enterprise resource planning (ERP) system together with Excel macros. The macros have four important limitations. First, the macros are separate from the ERP system. Second, they are relatively time-consuming to operate and configure. Third, they do not offer material or capacity simulation. Four, their ability to generate a component level forecast using statistical methods is limited. The company is considering replacing the macros with a better solution.

### 2.3.2 Research process

Avison et al. (1999) describe action reseach as an iterative process involving researchers and practioners acting together on a particular cycle of activities, including problem diagnosis, action intervention and reflective learning. Explicit criteria should be defined before performing the research in order to later judge its outcome.

Susman and Evered (1978) divide action research into five process steps: diagnosing, action planning, action taking, evaluating and specifying learning. Coghlan (2001) defines insider action research as a variant of action research. The persons who undertake an insider action research project are members of the organization being researched. They want to remain members within their desired career paths when the research is completed. In this thesis insider action research is used to solve the research problem.

### 2.3.3 Data collection and analysis

The steps of the action research and the corresponding chapters are presented in Figure 4. The whole process is performed in the case company.

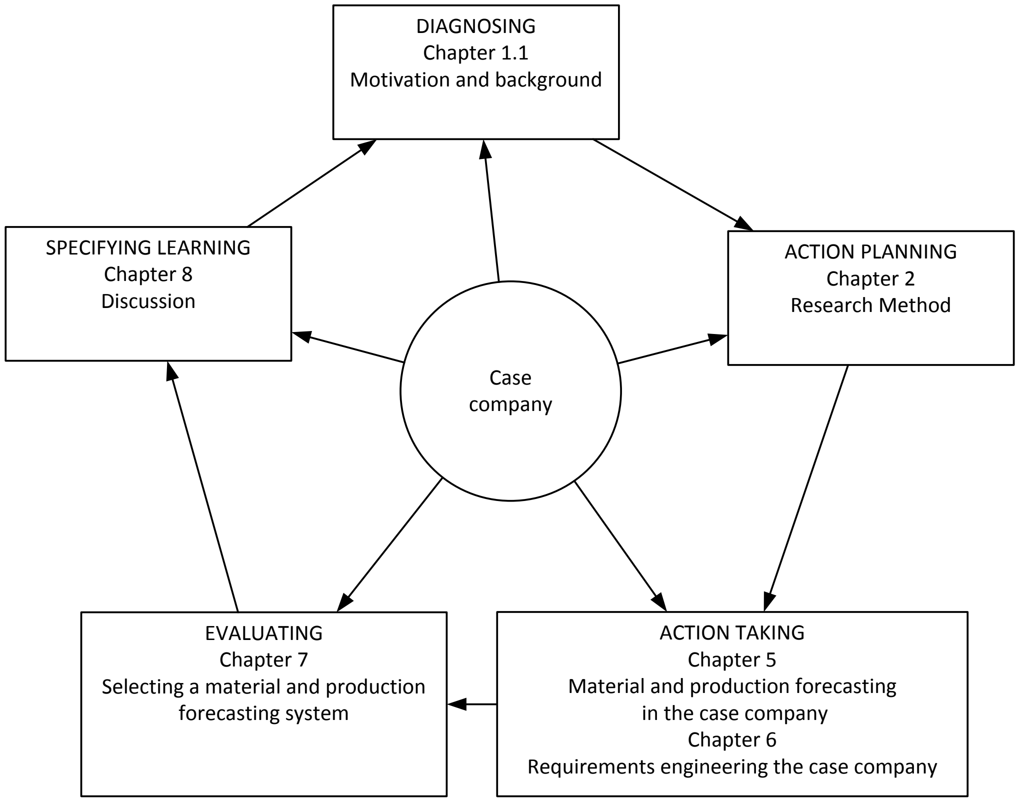


**Figure 4: The steps of action research conducted (Susman and Evered 1978)**

In the diagnosing phase the research problem was identified. The case company wanted to find out how to generate a material and production forecast using software systems. The current process was not accurate enough. The forecast was generated using the ERP system together with Excel macros. A new process had to be designed and the macros needed to be replaced with a better solution.

In the action planning phase alternative courses of action were considered for solving the problem. The research problem was divided into three research questions. First, an ideal demand management process for the case company was designed. Second, a suitable requirements engineering process was selected. Requirements for a tool supporting the demand management process were derived. Third, the validity of the requirements was tested by evaluating a couple of potential forecasting tools against the requirements.

In the action taking phase a course of action was selected. Answering to the first research question was started by evaluating the maturity level of the current demand management process. The targeted level of S&OP implementation was defined by interviewing the process owner. The current process was compared to three identified processes in the literature review. Based on the differences, an ideal demand management process was designed.

Answering to the second research question was started by categorizing stakeholders. Seven important stakeholders were interviewed. Based on the interviews, a use case diagram was drawn. A detailed list of requirements was derived by analysing the interview questions more thoroughly. Requirements were extracted and categorized into six clusters. Contradictory constraints were identified within each cluster. Requirements were prioritized.

In the evaluation phase the results of the requirements engineering process were evaluated. This was done by comparing four possible tools against prioritized requirements. The number of requirements each tool fulfilled, suitability to the case company's information system architecture and possible risks were evaluated.

Finally, the research questions were answered and the learnings discussed. The learnings are based on experiences of the empirical study. The action research described in this thesis consisted of one iteration cycle. Further iterations of the action research cycle can be used in the case company to improve the requirements engineering process.

# 3 Material and production forecasting

## 3.1 Maturity models

### 3.1.1 Overview of the models

A first step in developing a business process is to know its current maturity level. Lapide (2005) presents a maturity model which has four stages and three dimensions. The dimensions are “meeting practices”, “process integration” and “technology-enablement”. Grimson and Pyke (2007) present a model which has five stages and five dimensions. The dimensions are “meetings and collaboration”, “organization”, “measurements”, “information technology” and “S&OP plan integration”. In the following chapters I shall compare the dimensions that are similar in both frameworks. They are visualized in Figure 5.

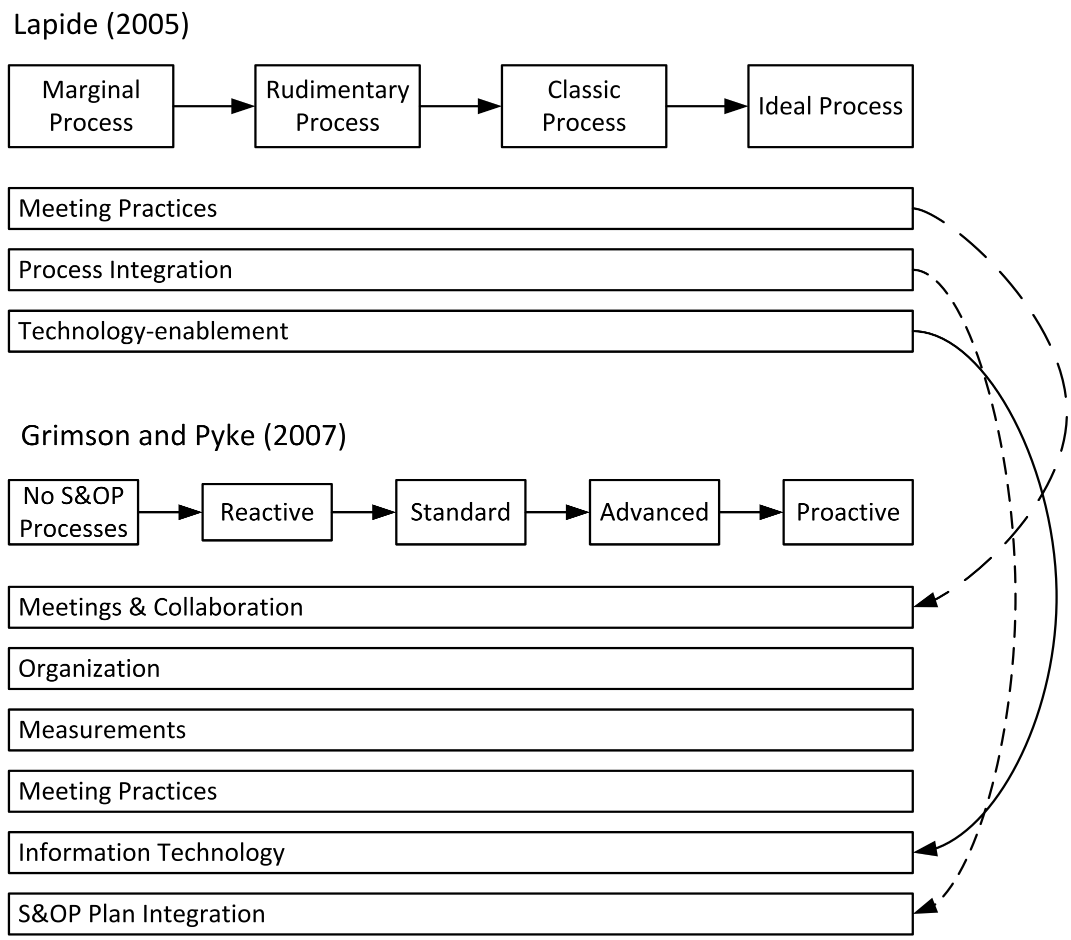


**Figure 5: S&OP maturity frameworks**

### 3.1.2 Meeting practices

The comparison of meeting practices evaluation is visualized in Figure 6. Lapide (2005) determines four levels of meeting practices. On stage 1, meetings only take place on a sporadic basis. On stage 2, meetings are scheduled and routinely held. However, the attendance is spotty. On stage 3, meetings are routinely held and attended. On stage 4, the meetings are event-driven. They are scheduled on-demand only when someone wants to change any of the existing plans or when a supply-demand imbalance is detected.

Grimson and Pyke (2007) determine five levels of meeting practices. On stage 1, there are no planning meetings and virtually no collaboration between sales and operations departments. On stage 2, sales and operations issues are discussed primarily in the context of financial goals, rather than for the purpose of integrating plans. On stage 3, pre-meetings within function make sure that executive S&OP meetings focus specifically on integrated S&OP. On stage 4, top customers and suppliers actively participate in the meetings. On stage 5, the meetings are event-driven. Rather than waiting until the regularly scheduled S&OP meeting, the S&OP team will meet immediately if needed.

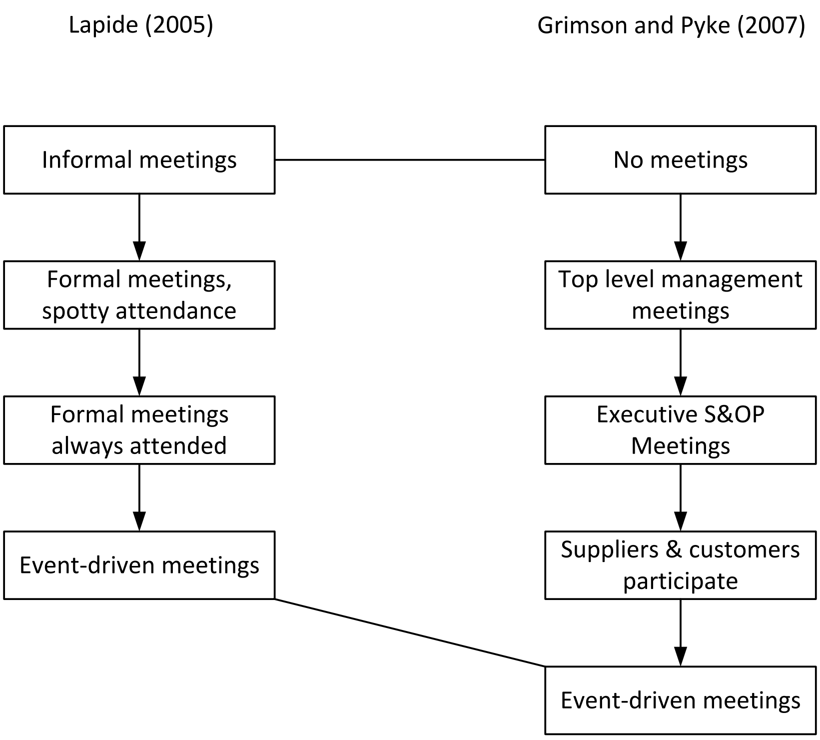


**Figure 6: Meeting practises evaluation in maturity level frameworks**

Both authors agree that if meetings are not arranged at all or if they only take place on a sporadic basis S&OP meeting practices are at the lowest level. Furthermore, they agree that at the highest level S&OP meetings are event-driven. Lapide (2005) evaluates meeting practices based on attendance rate and how formal the meetings are. Grimson and Pyke (2007) evaluate meetings practices mainly based on participants involved. At the lowest levels only top management is involved. At the highest levels the meetings involve participants from several companies.

### 3.1.3 Process integration

The comparison of process evaluation is visualized in Figure 7. Lapide (2005) determines four levels of process integration. On stage 1, planning processes are disjointed. Each department has its own demand plan and information is not shared between departments. On stage 2, planning processes are interfaced. Multiple demand plans are developed by the demand-side organizations and the information is shared with each other. On stage 3, the planning processes are integrated between demand-side and supply-side organizations. On stage 4, plans are aligned with the plans of both suppliers and customers.

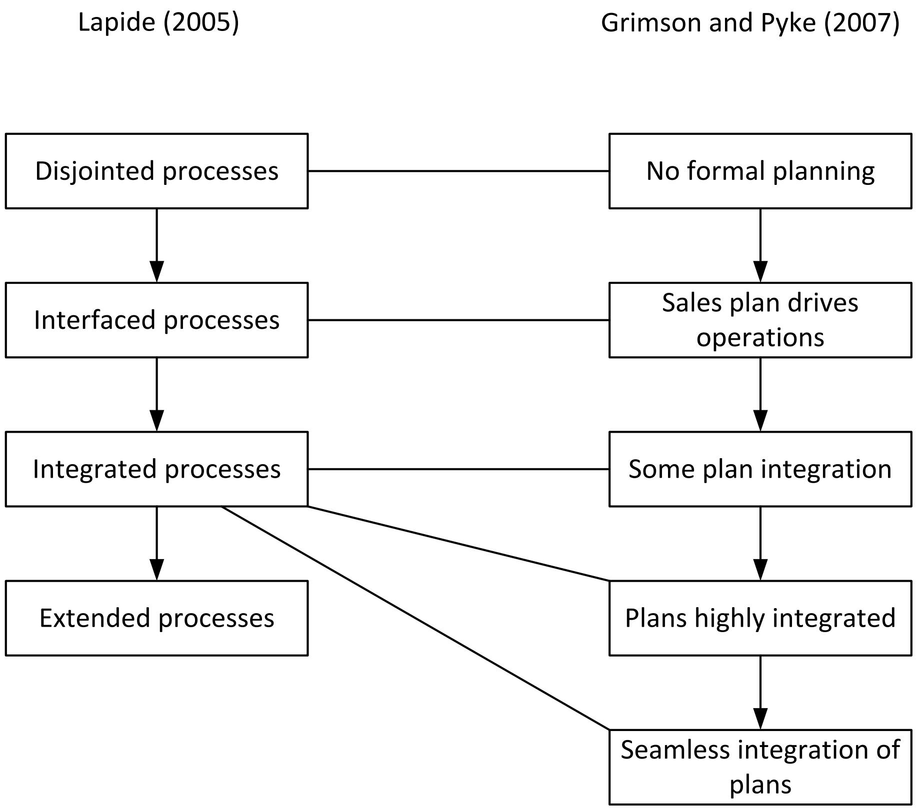


**Figure 7: Process evaluation in maturity level frameworks**

Grimson and Pyke (2007) determine five levels of process integration. On stage 1, operations attempts to meet incoming orders with no advance information on sales forecasts. On stage 2, sales plan drives operations plan and S&OP is purely a one way process. On stage 3, forecast is developed bottom-up. The plans are then tempered by business and financial goals. On stage 4, the process to develop the sales and operations plan is collaborative rather than solely driven by sales. On stage 5, the company has a seamless planning process, which is optimized concurrently for demand and supply to maximize profitability.

Both authors determine the level of process integration based on how well plans are integrated. Lapide (2005) emphasizes the number of participants involved in the shared plan. At the lowest level the information is shared inside one department. At the highest level information is shared in the whole supply chain. Grimson and Pyke (2007) emphasize the nature of communication. At the lowest levels the planning is a one way process and the communication is sequential At the highest levels planning is a two way process and the communication is collaborative.

### 3.1.4 Information technology

The comparison of technology evaluation is visualized in Figure 8. Lapide (2005) determines four levels of information technology. On stage 1, very little software is needed to enable a marginal S&OP process. Each department can just use a spreadsheet to develop their isolated plans. Spreadsheet technology is sufficient when there is no need integrate the plans. On stage 2, each organization uses their own standalone enabling software technology, since demand and supply plans are separately developed. On stage 3, demand side and supply-side software applications are integrated, since final demand and supply plans need to be jointly developed. On stage 4, integrated demand-planning technology architecture is used. This system allows users to instantaneously evaluate any changes being discussed. The system can re-optimize the plans at any time.

Grimson and Pyke (2007) determine five levels of information technology. On stage 1, a company has few spreadsheets owned, but not shared, by individual managers. On stage 2, spreadsheets and data are separately owned and updated, but there is some manual consolidation. On stage 3, companies centralize information in an automated way, and then employ revenue or operations planning software. On stage

4, the company has revenue and operations optimization software, although the plans are optimized sequentially rather than jointly. On stage 5, firms employ real-time, integrated solutions that jointly optimize sales decisions, such a pricing, with operations decisions, such as production schedules.

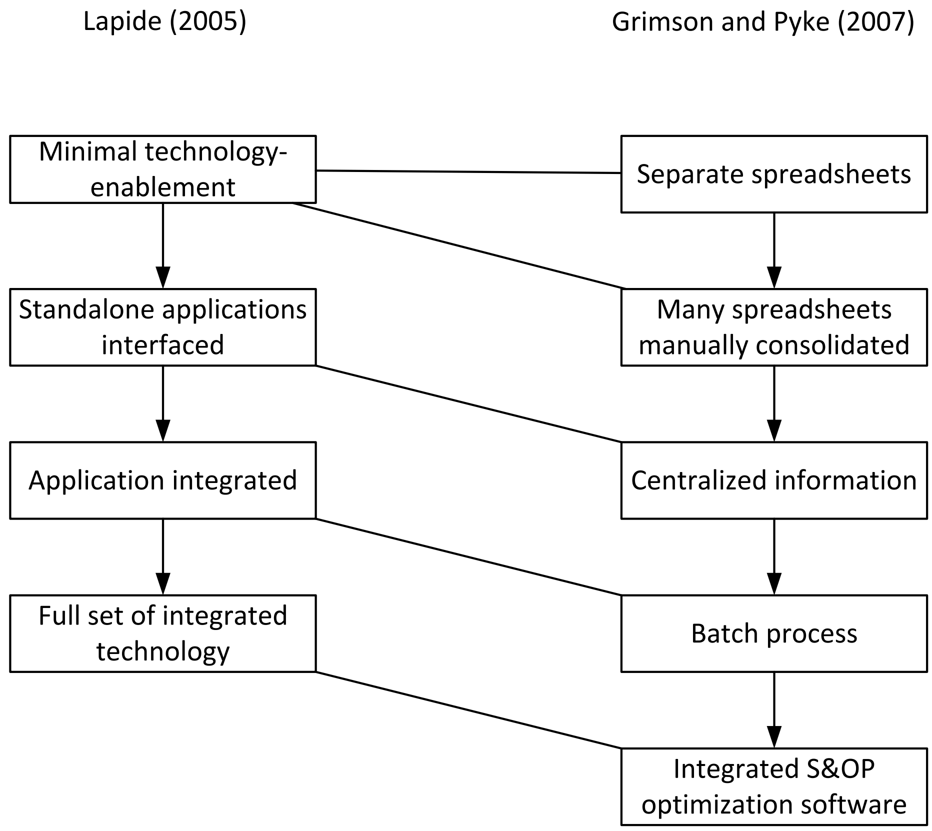


**Figure 8: Technology evaluation in maturity level frameworks**

Both authors determine the level of information technology based on the integration level. On the lowest levels, individual spreadsheets are used to store information. These spreadsheets might be manually consolidated. On higher levels the consolidation is done automatically and the information is centralized. At the highest level the consolidation can be done in real time when any of the plans is changed.

## 3.2 Forecasting on product family level using judgmental methods

### 3.2.1 Overview of the processes

According to Thomé et al. (2012) most sales and operations planning is done at the product family level. Meyer and Utterback (1993) define product family as a set of products that share a common platform but have specific features and functionality required by different sets of customers. In S&OP literature predicting product family level demand is called aggregated level forecasting.

Figure 9 presents two sales and operations planning process models. Wallace (2006) presents a five-step sales and operations planning process. In the first step, information needed in the process is consolidated. In the second step, a new demand forecast is agreed on. In the third step, a new operations plan is generated. In the fourth step, demand and supply plans are reconciled. In the fifth step, the new plan is confirmed.

Lapide (2002) presents a three-step process. In the first step, an unconstrained demand forecast is developed. In the second step, the demand and supply sides of business are reconciled. In the third step, the forecast is generated at the most detail level.

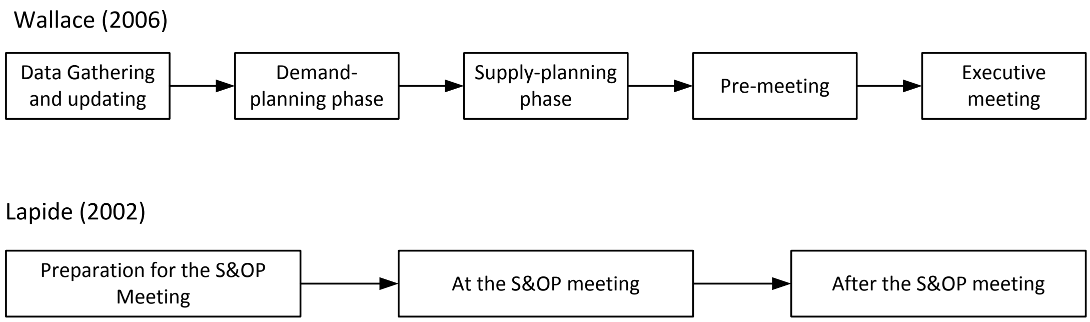


**Figure 9: Sales and operations planning process models**

In the following chapters I shall compare these two the sales and operations planning process models. According to Grimson and Pyke (2007) the five-step process is typical for S&OP. Therefore, I base my analysis on it. Lapide (2004) presents 12 success factor of S&OP process. I present the ones that relate to at least one of the five process steps of S&OP.

### 3.2.2 Data gathering and updating

According to Wallace (2006), the "data gathering and updating" phase consists of collection and collation of historical demand, generation of the new statistical forecast, and so forth.

According to Lapide (2002), these activities are done in the phase "preparation for the S&OP meeting". In that phase, a baseline unconstrained demand forecast should be developed. The forecast should incorporate historical trends in demand, as well as all known impacts to future demand. Often historical trends are incorporated using statistical forecasting techniques. The forecast should be based on unconstrained demand rather than shipment data; because the latter may distort true customer demand if supply constraints have routinely impacted demand.

According to Lapide (2004) this baseline forecast is important because it forms a working draft from which S&OP participants develop final supply and demand plans. It should be unbiased, unconstrained, and incorporate all known impacts to future demand. To keep it fully factually-based, the baseline forecast is most often developed using statistical forecasting methods.

### 3.2.3 Demand-planning phase

According to Wallace (2006), the demand-planning phase consists of forecast updates, new product requirements and creation of the consensus forecast approved by the senior sales and marketing executives. The primary responsibility for this phase is held by sales and marketing.

According to Lapide (2002), these activities are done in the phase "preparation for the S&OP meeting". The baseline forecast should be adjusted to include all known impacts on demand by incorporating marketing intelligence that includes recent competitor actions and future marketing promotion and pricing impacts. The forecast needs to be aggregated and translated for different participants to look at. For example, marketing and brand managers may need to review it in terms of product groups and brands, possibly by units and dollars. It is very important to document the forecast by explaining the assumptions upon which it was created. This entails describing the extent to which the forecast is based on historical trends versus based on marketing factors.

According to Lapide (2004) the baseline demand forecast should be unconstrained and incorporate all known factors that could impact future demand, including new product introductions and promotions.

### 3.2.4 Supply-planning phase

According to Wallace (2006), the supply-planning phase consists of the generation of a new operations plan that reflects forecast changes and inventory shifts, and the identification of key capacity problems. The primary responsibility for this phase is held by operations.

According to Lapide (2002), these activities are done in the phase "preparation for the S&OP meeting". In that phase, a rough-cut supply analysis needs to be conducted to determine the extent to which the unconstrained demand forecast will be limited by supply constraints. This should result in the development of an initial supply plan. As with the demand forecast, the supply plan should be documented. According to Lapide (2004), the rough-cut supply plan should include all known supply capacities and limitations – such as scarce inventories and limitations.

### 3.2.5 Pre-meeting

According to Wallace (2006), the pre-meeting contains the reconciliation of the demand plan and the supply plan, decision-making regarding how to rebalance demand and supply where necessary, development of alternative scenarios where appropriate, and formulation of recommendations and agenda for the executive meeting. The primary responsibility of this phase is held by managers from sales and marketing, operations, finance and product development.

Lapide (2002) does not have a separate pre-meeting and executive meeting. These activities are done in the S&OP meeting phase. It should involve participants from the marketing, sales, logistics and manufacturing departments that influence supply and demand, as well as from the finance department. It starts with a discussion of the baseline forecast and the rough-cut supply plan. Throughout the meeting, information about impacts on supply and demand needs to be shared and discussed.

Four success factors by Lapide (2004) relate to the pre-meeting phase. First, S&OP needs to be a cross-functional process that involve demand-side managers, supply-side managers and finance personnel. There needs to be active participation during the meetings. Second, a key aspect of an S&OP process is that it is comprised of routine meetings that are held on a periodic basis. Many companies hold them monthly. Third, the S&OP meetings should follow fixed agenda in a pre-specified amount of time. The meetings need to include a review of how well the previous plans were met. Fourth, S&OP needs to be conducted as a repeatable process that runs on-time and according to the schedule. To accomplish this, it should be organized and run by a responsible organization. The person in charge of the S&OP process is usually not a high-level executive – as such an individual might dominate the meetings.

### 3.2.6 Executive meeting

According to Wallace (2006), the executive meeting contains decisions on items where the pre-meeting team was unable to evaluate the new sales and operations plan against the company's strategy, policy and risk parameters; and relate the dollarized version of the S&OP to the business plan and make appropriate changes where necessary. The primary responsibility of this phase is held by executive management, up to and including the leader of the business unit.

According to Lapide (2002), these actions are done in the S&OP meeting phase. The agenda for the S&OP process should be set up to ensure closure. To accomplish this, participants need decision-making authority. All decisions need to be documented so that final plans can be clearly communicated after the meeting. The meeting must end with everyone agreeing and taking accountability for the constrained demand forecast.

Two success factors by Lapide (2004) relate to the executive meeting phase. First, participants need to be empowered by executive team to make decisions based on their beliefs. While this can be accomplished by building meetings that involve only senior managers, most company executives empower their subordinate director-level managers to attend the meetings on behalf of their department and to make decisions they support. Second, S&OP should be a collaborative process designed to lead to consensus-based plans. Every stakeholder needs to be able to quickly create, review and revise plans. The process needs to be set up that allows all members to easily provide feedback to work-in-progress plans.

## 3.3 Forecasting on product level using judgmental methods

### 3.3.1 Overview of the models

Sales and operations planning can be implemented on product level. In S&OP literature products are called stock keeping units. Mungkung et al. (2012) define a stock keeping unit (SKU) as a specific code used to identify each unique product in a business. Thomé et al. (2012) give examples of product level S&OP and S&OP processes that combine both product family and product level forecasts.

Singh (2010) has recognized five systemic flaws in how S&OP programs are viewed and run. He lists answers to these flaws. First, a company needs a formally defined S&OP function. Second, S&OP should be on the executive agenda. Third, S&OP should start with a balanced demand–supply plan at the product level. Fourth, performance metrics should be applied. Fifth, supply chain leaders should use predefined, documented playbooks to manage their processes.

Bower (2005) presents a five-step S&OP process. It is illustrated in Figure 10. In the first step, business leaders review product life cycles. In the second step, they review demand plans. In the third step, they review supply plan to align business strategy with business reality. In the fourth step, gaps between results and the business strategy are identified. In the fifth step, senior management reviews the plans.

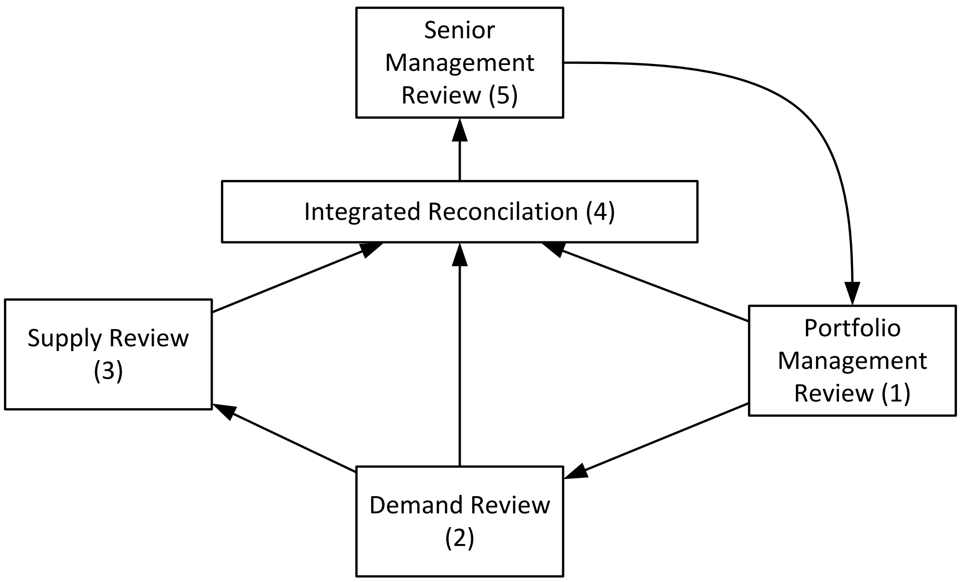


**Figure 10: S&OP process (Bower 2005)**

In the following chapters I shall compare Singh’s and Bower’s models. I have identified four topics which are discussed in both models. These topics are “organization”, “lack of senior management support”, “bottom-up and top-down forecast in conflict” and “metrics”. I try to find out the typical flaws in S&OP implementations and how these issues can be resolved.

### 3.3.2 Organization

According to Singh (2010) a fundamental reason to S&OP failure is the lack of formally defined S&OP function. At best, companies set up small cross-functional S&OP teams. At worst, they form ad hoc teams from different functional groups. The required S&OP function should integrate all the core and supporting functions that have an impact on demand-supply integrations. It should have a named leader who reports directly to the chief operating officer.

Bower (2005) lists three threats relating organizational issues. The first threat is that the S&OP leader owns supply and demand planning. While the S&OP leader should be familiar with supply and demand planning operations, the leader should not be responsible for the success of these areas. This is because the S&OP process requires totally unbiased measurement, evaluation and action. According to Bower this won’t happen if the S&OP process leader is also responsible for any one of the core operational areas covered by the process. The second threat is that S&OP ignores product life cycle management. In many companies, products that are going through life cycle changes are not managed as a part of the S&OP process. This is surprising, because products going through lifecycle changes are difficult to forecast. According to Bower, new products typically have the worst forecasting errors. The third threat is that office politics undermine progress. According to Bower trying to build consensus in a sensitive environment can be difficult. The meetings should have a fact-based culture of straight talk.

The authors agree that sales and operations planning should be a separate function. Its leader should be able to focus on long term planning full time. S&OP unit needs to communicate frequently with other organizational units. It has to be familiar with short-term planning and product life cycle statuses.

### 3.3.3 Lack of senior management support

According to Singh (2010), typically S&OP related activities are relegated to operational levels. The activities should be on the agenda of the chief financial officer or the chief operating officer. S&OP processes need to be driven top-down. Every S&OP discussion should start and end with financial metrics that are driven by senior management.

According to Bower (2005) lack of decision making is typical for immature S&OP implementations. According to him, improving the decision making is not difficult if the parties are willing. At the end of each S&OP review meeting, the facilitator should recap open issues along with the action plans for resolution. Both authors think that senior management support is required. Even the decisions which do not require senior management's sign off need to be backed up by an analysis of financial implications.

### 3.3.4 Bottom-up and top-down forecasts in conflict

Singh (2010) describes a model where the operations group creates a bottom-up plan using sophisticated forecasting tools. However, after the numbers are summarized, there is always a mismatch between the bottom-up operational plan and the top-down financial plan. It is typical that the top-down financial plan takes precedence, and the bottom-up operational plan is changed by altering the product mix to match the financial plan. The author proposes two changes to that model. First, what it required is a two-way collaboration to take into account the realistic operational picture and to reconcile with the financial numbers. Second, the sales team should provide information on the product level. It is typical that the sales teams provide information only on the product family level. According to the author the sales teams often have richer information.

Bower (2005) lists two threats relating to bottom-up and top-down forecast being in conflict. First threat is a mismatch between S&OP and corporate strategy. Corporate strategists spend a lot of time and resources developing commercial and supply chain strategies. S&OP could help organizations connect strategy and execution, and then provide the measurement and a forum to assure alignment. Second threat is that a single number forecast is not reality-based. Working to gain consensus around a single number forecast is an essential part of S&OP. However, there is more to consider than just whether a single number forecast is created. The single number forecast should be based on insight, data, trends and confirmed facts.

Both authors think that the consolidation of top-down and bottom-up forecasts can be difficult. Singh (2010) suggests two-way collaboration and performing analysis on product level. Bower (2005) proposes using corporate strategy as an input and basing the forecast on facts.

### 3.3.5 Metrics

According to Singh (2010) there can never be real discipline in the demand plan unless those responsible for demand are also made accountable for the costs that the forecast produces. Sales must be held responsible for the costs associated with inventory and expedites that are typical consequences of poor demand planning.

According to Bower (2005) metrics are vital to ensure success in any S&OP process. However, very few people want their work evaluated in public on a monthly basis. Both authors think that metrics are vital in an S&OP planning process. Salespeople's total compensation should take into account the cost of poor demand planning.

## 3.4 Forecasting on component level using statistical methods

### 3.4.1 Overview of the models

In the previous chapters I have presented how a forecast can be created using judgmental methods. Statistical methods can be used as an alternative to them. The forecast can be created simply by extrapolating past data with no human intervention. Alternatively, the statistical methods can be used to generate a baseline forecast which is changed by the forecasters when necessary.

Chase (1997) divides statistical methods into time series methods and causal methods. Time series are techniques built on the premise that future sales will follow the pattern of past sales. The methods are well suited to situation where sales forecast is needed for a large number of items. The techniques include naive method, moving average, exponential smoothing, decomposition and Box-Jenkins. Causal methods are built on the premise that future sales of a particular product are closely associated with changes in some other variables. The methods include simple regression, multiple regression and econometrics.

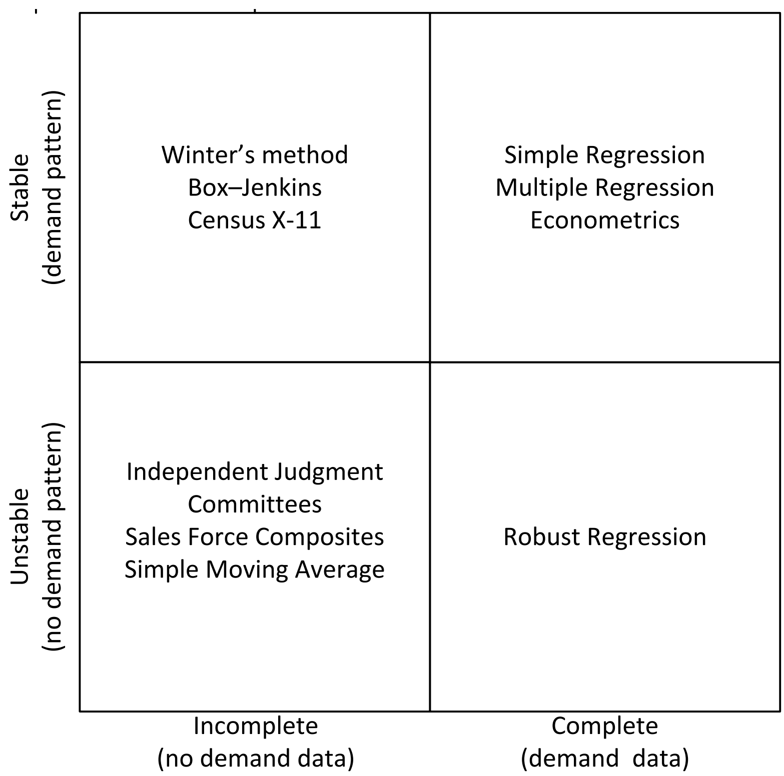


**Figure 11: Selecting the forecasting method (Chase 1997)**

Chase (1997) presents a framework to select the forecasting method based on the product portfolio type. The framework is visualized in Figure 11. The portfolio is either incomplete or complete and either unstable or stable. Incomplete refers to having limited sales history for a particular item and not having the required causal variables. Complete refers to having all the required data for a particular item. Unstable refers to having no distinct pattern in the demand of a particular item. Stable refers to data that has a distinct pattern associated with it, such as seasonality or trend.

According to the author the products that have incomplete data and are unstable (see the lower left hand quarter) can only be forecasted using independent judgment, committees, sales force composites or simple moving average. Sales force composites mean that the future demand is estimated based on the total amount that each salesperson anticipates being able to sell in their region. Moving average means the average of previous n data points.

If the data is stable but incomplete (see the higher left hand quarter), the author recommends time series methods. They include Winter's method, Box–Jenkins and Census X-11. Winter's method is a three parameter exponential smoothing technique. Box–Jenkins combines the key elements from both time series and regression models. Census X-11 is a seasonal adjustment process for decomposing time series data into trend-level, seasonal index and irregular components.

If the data is complete and indicates distinct pattern (see the higher right hand quarter), the author recommends simple regression, multiple regression and econometrics. In simple regression two variables are thought to be systematically connected by a linear relationship. In multiple regression more than two variables are thought to be connected. Econometrics is the application of mathematics, statistical methods, and computer science to economic data.

If the data is complete and has no distinct pattern (see the lower right hand quarter), the author recommends robust regression. Robust regression is less sensitive to observation points distant from other observations than other regressions models. It seeks to find the relationship between one or more independent variables and a dependent variable.

Sanders and Manrodt (1994) surveyed forecasting practices at 500 US corporations. According to them managers rely heavily on judgmental forecasting methods. Statistical methods are not heavily used although they provide more accurate or less expensive forecasts in many situations. The major obstacles to using statistical methods are lack of relevant data and low organizational support. In the following chapter I shall compare the time series techniques presented by Chase (1997) to their findings.

### 3.4.2 Popularity of the models

The naive method assumes future sales will replicate past sales. According to Sanders and Manrodt (1994) 84 % of managers are very familiar with the naive method. It is typically used from immediate to medium forecast periods on all corporate forecast levels. Less than 20 % of managers are satisfied with it and over 50 % are dissatisfied. It is used more often in small firms than in large firms.

Moving average levels out small random fluctuations. According to Sanders and Manrodt (1994) 96 % of managers are very familiar with the technique. It is the best known quantitative method among US managers. It is typically used on short to medium forecast periods on product line and product family levels. 45 % of managers are satisfied with it.

Exponential smoothing is a weighted average of previous data points. The basic premise is that the volumes for the most recent periods have more impact on the forecast and therefore more weight. According to Sanders and Manrodt (1994) 84 % of managers are very familiar with exponential smoothing. It is typically used from immediate to medium forecast periods on product line to corporate level forecasts. 41 % of managers are satisfied with it and 28 % of managers are dissatisfied with it. It is used more often in large firms than in small firms.

Decomposition is based on the assumption that sales are affected by four basic elements: trend, seasonal influences, cyclical influences and random influences. According to Sanders and Manrodt (1994), 57 % of managers are very familiar with the decomposition method. 35 % of managers are unfamiliar to it. It is used from short to long forecast periods on all corporate forecast levels. 40 % of managers are satisfied with it and 27 % of managers are dissatisfied with it. It is used more often in large firms than in small firms.

Box–Jenkins combines key elements from both time series and regression models. According to Sanders and Manrodt (1994), 49 % of managers are unfamiliar with it. It is used for all time horizons and forecast levels. 49 % of managers are dissatisfied with it. It is used more often in large firms than in small firms.

# 4 Requirements engineering

## 4.1 Stakeholder classification

### 4.1.1 Overview of the models

Ballejos and Montagna (2008) define project stakeholder as “any individual, group, or organization that can affect or be affected by the system under study and that have direct or indirect influence on its requirements”. According to them identifying the right stakeholders is of paramount importance in a requirements engineering process. By using a framework to classify stakeholders the practitioners can make sure that all relevant stakeholder groups are included.

Alexander and Robertson (2004) present an onion model for stakeholder classification. Figure 12 presents the model, which has three zones around the product being built. “The kit” is the hardware and software under development. “Our system” is the kit plus its human operators and the rules governing its operation. “The containing system” is our system plus any human beneficiaries of our system. “The wider environment” is the containing system plus any other stakeholders.

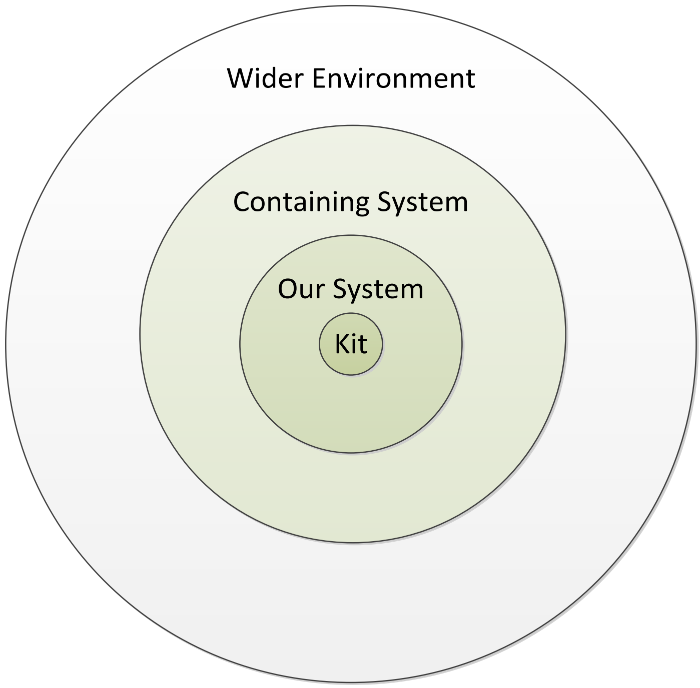


**Figure 12: The onion model (Alexander and Robertson 2004)**

Ballejos and Montagna (2008) classify stakeholders into internal and external stakeholders. Internal stakeholders are involved in the participating organizations. They include managers and employees. External stakeholders are included because of having a necessary point of view or interest for the project. They include customers, suppliers, auditors, regulators, main investors, consultants and experts.

Damian (2007) classifies stakeholders into two groups. The first group is knowledgeable of the client's application domain and user's needs. This group includes the client's IT department and business community and the software development organization's field personnel and marketing department. The second group is the project execution team. This group includes the development organization's project and product management teams.

Fricker (2010) divides stakeholders into direct and indirect ones. Direct stakeholders concern software operation and include the product's user. Indirect stakeholders influence software success indirectly and include development, execution, financing and regulation.

Paech et al. (2005) divide stakeholders into two dimensions using Nokia as an example case. The first dimension consists of five views: marketing, user, high-level system, low-level system and software. The second dimension consists of three audiences: customer, customer projects and platform project.

Sharp et al. (1999) classify stakeholders into baseline stakeholders, supplier stakeholders, client stakeholders and satellite stakeholders. Baseline stakeholders are users, developers, legislators and decision-makers. Supplier stakeholders provide information or supporting tasks to the baseline stakeholders. Client stakeholders process or inspect the product of the baseline stakeholders. Satellite stakeholders interact with the baseline in a variety of ways.

In the following chapters I shall use the onion model by Alexander and Robertson (2004) to categorize the stakeholders presented in these models. I base my analysis on the onion model because it is comprehensive and its roles are explicitly defined.

### 4.1.2 Our system

Alexander and Robertson (2004) place normal operators, maintenance operators and operational support into our system. This group contains roles that operate and maintain the equipment and deliver its results. A normal operator is a role that gives routine commands and monitors outputs from the product. The role delivers the results to functional beneficiaries. Maintenance operator is a role that services hardware, and diagnoses and fixes faults. Operational support is a role that advises normal operation about how to operate the product. Equivalents to these roles in other models are presented in Table 2.

**Table 2: Our system (Alexander and Robertson 2004)**

| Role | Equivalents in other models |
|---|---|
| Normal operator | direct user (Sharp et al. 1999)<br>operator (Ballejos and Montagna 2008)<br>user (Damian 2007)<br>user (Fricker 2010) |
| Maintenance operator | client's IT department (Damian 2007)<br>expert (Ballejos and Montagna 2008)<br>maintainer (Sharp et al. 1999)<br>service and support (Fricker 2010) |
| Operational support | service and support (Fricker 2010)<br>trainer (Sharp et al. 1999) |

Ballejos and Montagna (2008) and Damian (2007) include normal operators and maintenance operators in their models. According to Damian both roles are knowledgeable of the client's application domain and user's needs. The authors do not recognize operational support in their models. Sharp et al. (1999) and Fricker (2010) include all three roles in their models. According to Sharp et al. normal operators belong to the user baseline group and maintenance operators and operational support belong to the developer baseline group. According to Fricker all three roles are direct stakeholders.

### 4.1.3 Containing system

Alexander and Robertson (2004) place purchasers, champions, functional beneficiaries and roles responsible for interfacing system into containing system. Purchaser is a role that is responsible for having the product developed. Champion is a role that is responsible for initiating the development of the product, for obtaining funding for it, and for protecting the development from political pressures and funding cuts. Functional beneficiary is a role that benefits from the results or outputs created by the system. A responsibility for interfacing system is a role that has electronic or other interfacing to/from kit. Equivalents to these roles in other models are presented in Table 3.

**Table 3: The containing system (Alexander and Robertson 2004)**

| Role | Equivalents in other models |
|---|---|
| Purchaser | controlling (Fricker 2010)<br>product development manager (Paech et al. 2005)<br>product marketing manager (Paech et al. 2005)<br>product management team (Damian 2007)<br>project management team (Damian 2007)<br>responsibilities (Ballejos and Montagna 2008) |
| Champion | decision-makers (Ballejos and Montagna 2008)<br>software team leader (Paech et al. 2005)<br>system team leader (Paech et al. 2005)<br>senior managers (Fricker 2010)<br>software team leader (Paech et al. 2005)<br>system team leader (Paech et al. 2005) |
| Functional beneficiaries | functional beneficiaries (Ballejos and Montagna 2008)<br>indirect users (Sharp et al. 1999) |

Damian (2007) includes only purchasers in her model. According to her, they belong to the project execution team and are not knowledgeable of the client's application domain and user's needs. Paech et al. (2005) add champions to the model. Ballejos and Montagna (2008) add functional beneficiaries to the model. Sharp et al. (1999) have only functional beneficiaries on their model.

### 4.1.4 Wider environment

Alexander and Robertson (2004) place developers, consultants, financial beneficiaries, negative stakeholders, regulators and political beneficiaries into the wider environment. Developers are the ones who are involved directly in the development. Consultants are the ones involved in supporting some aspect of the system development, characteristically from outside the development organization. Financial beneficiaries are the ones that can benefit financially. Negative stakeholders are the ones that could be harmed by the system. Regulators are the ones that are responsible for regulating the quality, safety, cost or other aspects of the system. Political beneficiaries are the ones that can benefit in terms of power, influence or prestige. Equivalents to these roles in other models are presented in Table 4.

**Table 4: The wider environment (Alexander and Robertson 2004)**

| Role | Equivalents in other models |
|---|---|
| Developers | developer (Sharp et al. 1999)<br>developers (Ballejos and Montagna 2008)<br>development (Fricker 2010)<br>development organization’s project team (Damian 2007)<br>field personnel (Damian 2007)<br>production (Fricker 2010)<br>suppliers (Fricker 2010) |
| Consultants | consultants (Ballejos and Montagna 2008)<br>marketing department (Damian 2007)<br>marketing department (Fricker 2010)<br>product marketing manager (Paech et al. 2005) |
| Financial beneficiaries | customer (Fricker 2010)<br>financial beneficiaries (Ballejos and Montagna 2008)<br>key account manager (Paech et al. 2005) |
| Negative stakeholders | competitors (Fricker 2010)<br>negatives (Ballejos and Montagna 2008) |
| Regulators | regulators (Ballejos and Montagna 2008)<br>legislators (Sharp et al. 1999) |

Damian (2007) includes developers and consultants in her model. Fricker (2010) adds financial beneficiaries and negative stakeholders to the model. Ballejos and Montagna (2008) add regulators to the model. Sharp et al. (1999) has only developers and regulators in their model. Paech et al. (2005) has only consultants and financial beneficiaries in their model.

## 4.2 Requirements engineering process

### 4.2.1 Overview of the models

Zave (1999) defines requirements engineering as "the branch of software engineering concerned with the real-world goals for functions of and constraints on software systems. It is also concerned with the relationship of these factors to precise specifications of software behavior, and to their evolution over time and across software families".

Nuseibeh and Easterbrook (2000) divide requirements engineering into five process steps. The steps are "eliciting requirements", "modelling and analyzing requirements", "communicating requirements", "agreeing requirements" and "evolving requirements". The model is illustrated in Figure 13.


**Figure 13: Requirements engineering process (Nuseibeh and Easterbrook 2000)**

Sommerville (2011, p. 99) presents a spiral view of the requirements engineering process. The activities are organized as an iterative process around a spiral, with the output being a system requirements document. The requirements are developed to three different levels of detail. The levels are business requirements, user requirements and system requirements. The process includes four high-level activities. Feasibility study assesses if the system is useful to the business. Elicitation and analysis discovers requirements. Specification converts them into some standard form. Validation checks that the requirements actually define what the customer wants. The model is illustrated in Figure 14.

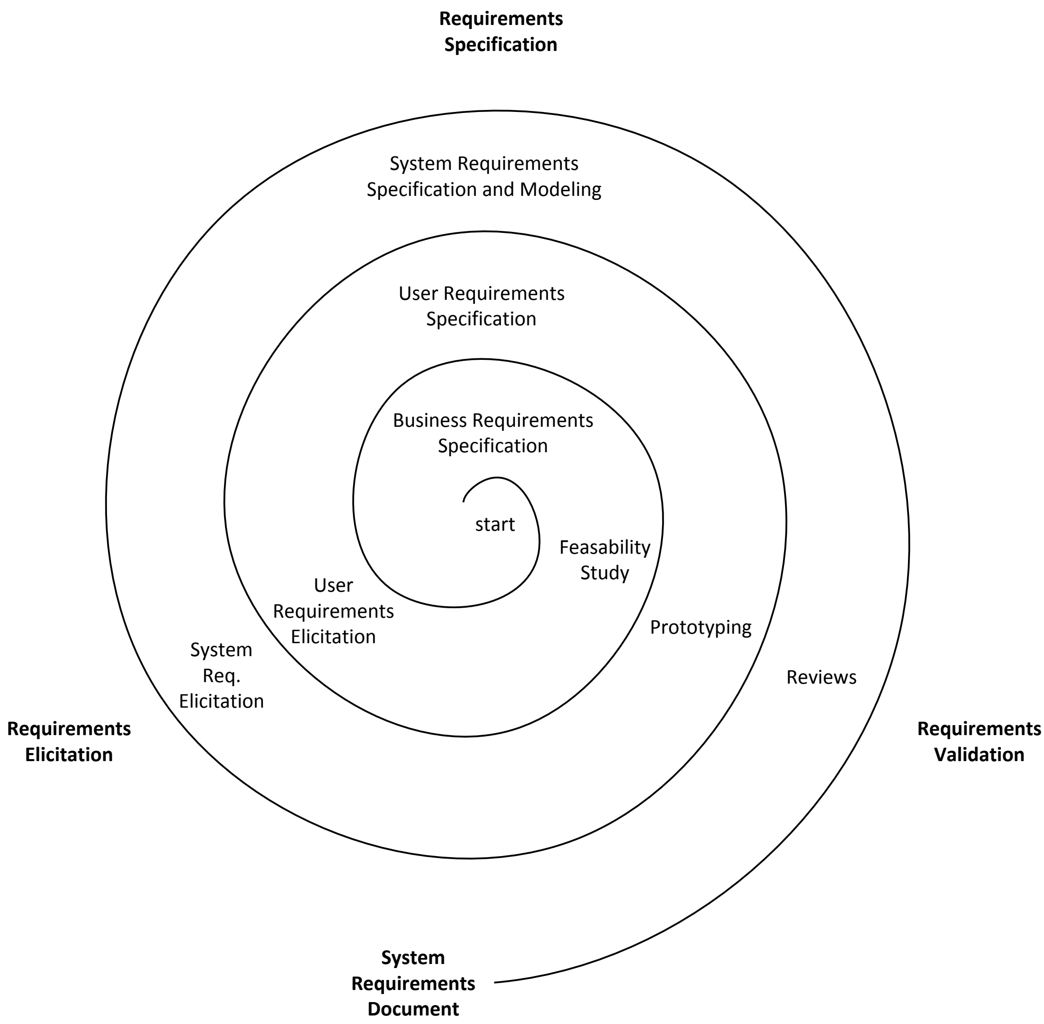


**Figure 14: Requirements engineering process (Sommerville 2011, p. 99)**

In the following chapters I shall compare the spiral view of the requirements engineering process by Sommerville (2011, p. 99) to the requirements engineering process model by Nuseibeh and Easterbrook (2000). I base my analysis on the latter model because it presents requirements engineering using five simple process steps.

### 4.2.2 Eliciting requirements

According to Nuseibeh and Easterbrook (2000) a requirements engineer needs to identify system boundaries, stakeholders and goals in the eliciting requirements phase. System boundaries define where the final delivered system will fit in the current operational environment. Stakeholders are individuals or organizations who gain or lose from the success or failure of the system. Goals denote the objectives a system must meet. Elicitation techniques involve traditional techniques, group elicitation techniques, prototyping, model-driven techniques and cognitive techniques.

In the spiral view by Sommerville (2011, p. 82–114) requirements elicitation is the process of gathering information about the required system and existing systems, and distilling the user and system requirements from this information. Sources of information during this phase include documentation, systems stakeholders and specifications of similar systems.

According to Sommerville (2011, p. 82–114) elicitation techniques include interviewing, scenarios and use cases. In the interviews, the requirements engineer puts questions to stakeholders about the system they currently use and the system to be developed. Requirements are derived from the answers to these questions. Scenarios are descriptions of example interaction sessions. They are used, because people often find it easier to relate to real-life examples rather than abstract scenarios. A use case identifies the actors involved in an interaction and names the type of interaction. An example use case diagram is presented in Figure 15. Actors in the process, who may be human or other systems, are represented as stick figures. Each class of interaction is represented as a named ellipse. Lines link the actors with the interaction.

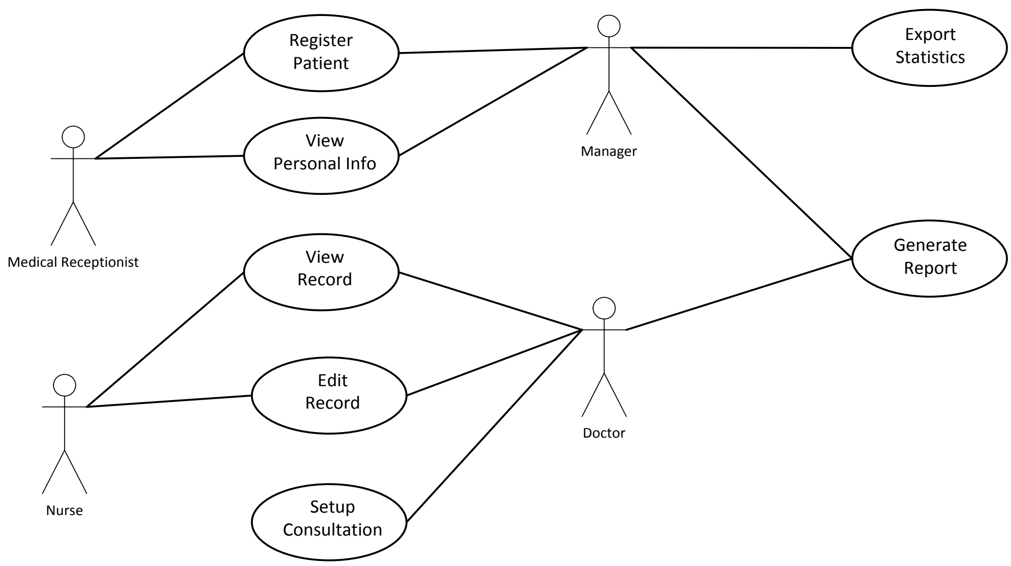


**Figure 15: An example use case diagram (Sommerville 2011, p. 107)**

### 4.2.3 Modelling and analyzing requirements

According to Nuseibeh and Easterbrook (2000) modelling and analyzing requirements consists of five areas. Enterprise modelling tries to capture the purpose of the system, by describing the behavior or the organization in which that system will operate. Data modelling explains what information the system needs to represent and how the information held by the system corresponds to the real world phenomena being represented. Behavioral modeling involves modelling behavior of existing and required stakeholders and systems. Domain modelling provides an abstract description of the world in which an envisioned system will operate. Modelling non-functional requirements describes properties of the system as a whole.

In the spiral view by Sommerville (2011, p. 101) "requirements classification and organization" takes the unconstructed collection of requirements, groups related requirements, and organizes them into coherent clusters. According to him, the most common way of grouping requirements is to use a model of the system architecture to identify sub-systems and to associate requirements with each sub-system.

### 4.2.4 Communicating requirements

According to Nuseibeh and Easterbrook (2000) requirements are documented with a variety of formal, semi-formal and informal languages. From logic to natural language, different languages have been shown to have different expressive and reasoning capabilities. Requirements should be written in a form that is readable and traceable by many, in order to manage their evolution over time. Requirements traceability determines how easy it is to read, navigate, query and change requirements documentation.

According to Sommerville (2011, p. 94–98) formal or informal requirements documents may be produced. User requirements are almost always written in natural language. According to Sommerville natural language is expressive, intuitive and universal. On the other hand it is potentially vague and ambiguous. Possible notations for system requirements are natural language sentences, structured natural language, design description languages, graphical notations and mathematical specifications.

### 4.2.5 Agreeing requirements

According to Nuseibeh and Easterbrook (2000) requirements validation is difficult for two reasons. First reason is philosophical in nature. The problem of validating requirements can be compared to the problem of validating scientific theories. They can never be proved correct through observation, they can only be refuted. This view suggests that requirements engineers should adopt the same stance that software testers take. They should conduct experiments trying to refute the current statement of requirements. Second reason is social. Stakeholders may have goals that conflict with each other. Requirements negotiation attempts to solve conflicts between stakeholders.

According to Sommerville (2011, p. 100–111) requirements prioritization and negotiation is concerned with prioritizing requirements and finding and resolving requirements conflicts through negotiation. Usually, stakeholders have to meet to resolve differences and agree on compromise requirements. Requirements validation is the process of checking that the requirements actually define the system that the customer really wants. During the requirements validation process, different types of checks should be carried out. These checks include validity checks, consistency checks, completeness checks, realism checks and verifiability checks.

### 4.2.6 Evolving requirements

According to Nuseibeh and Easterbrook (2000) managing change is a fundamental activity in requirements engineering. Requirements are added in response to changing stakeholder needs, or because they were missed in the initial analysis. Requirements are deleted usually during development to prevent cost and schedule overruns. Managing consistency in requirement specification as the requirements evolve is a major challenge. Requirement engineers need techniques and tools for configuration management and version control, and traceability links to monitor and control the impact of changes in different parts of the documentation.

According to Sommerville (2011, p. 111–114) requirements management is the process of understanding and controlling changes to system requirements. The requirements engineer needs to maintain links between dependent requirements. A formal process is needed for making change proposals and linking these to system requirements.

## 4.3 Information system selection

Ncube and Maiden (1999) present Procurement-oriented requirements engineering (PORE) as a method to select commercial off-the-shelf software (COTS). The process is presented on high level in Figure 16. It uses an iterative cycle to narrow down potential candidate systems. Requirements acquisition enables product selection and product selection informs requirements acquisition. The repetitive iteration cycles add detail to the requirements document and decrease the number of potential products.

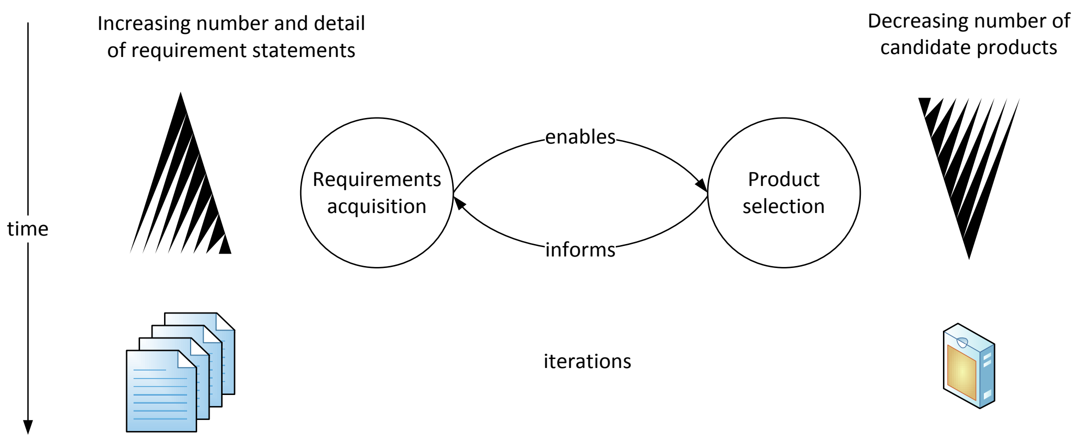


**Figure 16: Overview of the PORE's iterative process (Ncube and Maiden 1999)**

According to Summerville (2005) applications can be developed by acquiring new COTS systems and configuring them to interoperate with existing systems. According to him, selecting COTS software needs to be flexible. A critical set of requirements needs to be identified and a product that meets them needs to be chosen. The process consists of four steps which are illustrated in Figure 17.

Ottka (2014, p. 37) presents a modified version of PORE. It uses prioritized requirements from the initial requirements elicitation phase as a starting point. Possible tools are evaluated against the highest priority requirements. Any tools that do not meet the requirements are discarded. The process is repeated with descending priorities until only a small number of possible tools is left The process is presented on high level in Figure 18.

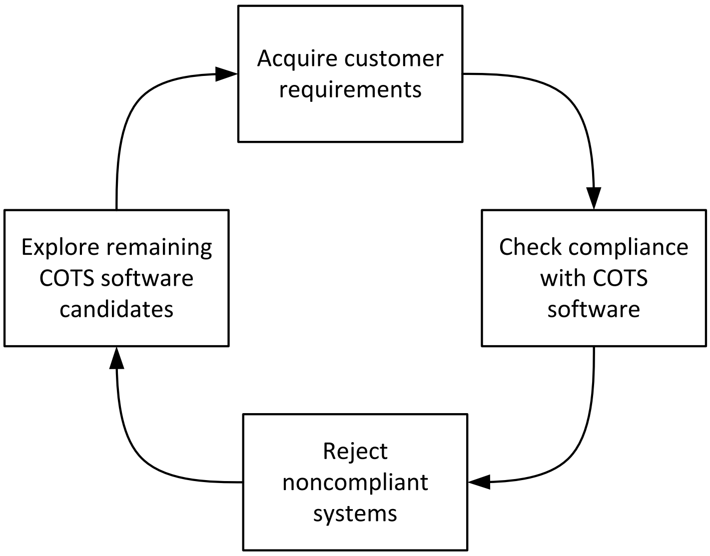


**Figure 17: The cyclical PORE (Sommerville 2005)**

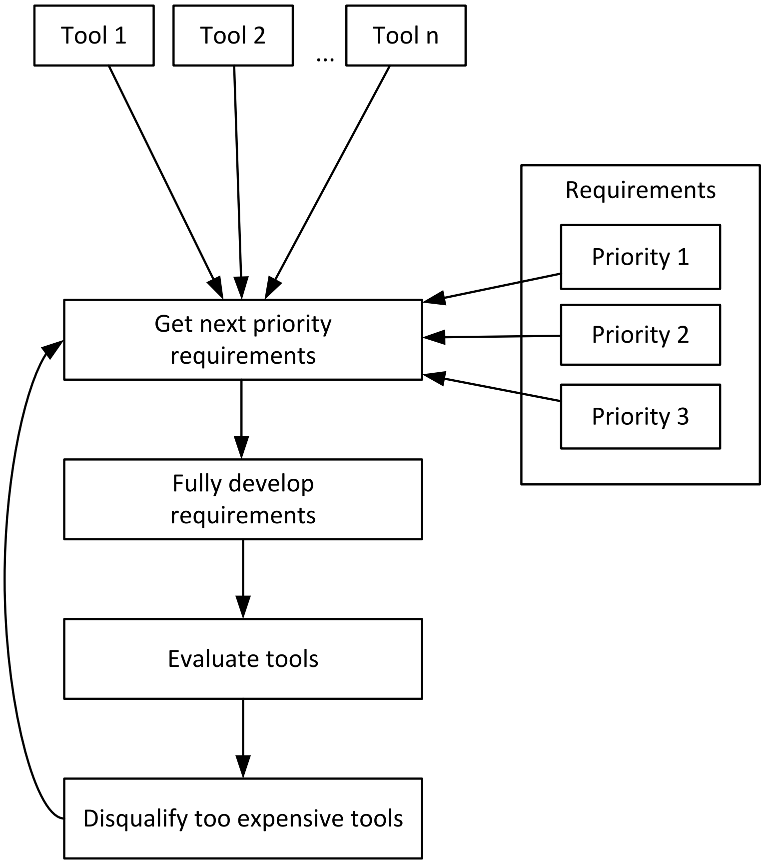


**Figure 18: Modified PORE (Ottka 2014, p. 37)**

# 5 Material and production forecasting in the case company

## 5.1 Maturity level of the current process

### 5.1.1 Meeting practices

Lapide (2005) evaluates meeting practices based on attendance rate and how formal the meetings are. In the case company demand review meetings are divided into equipment business area and system business area meetings. Meetings are scheduled and routinely held once a month. In the equipment business area they are also routinely attended. In the system business area the attendance is spotty. According to the framework equipment business area is on stage 3 of 4 and system business area is on stage 2 of 4.

Grimson and Pyke (2007) evaluate meetings practices mainly based on participants involved. The separate equipment factory and system factory meetings are pre-meetings within a business area. The demand review meeting focuses on integrated S&OP. According to the framework the case company is on stage 3 of 5. The average of 15 companies in the study is 2.65. According to the result, S&OP meeting practices in the case company are slightly above average.

To match the ideal meeting practices described in these two frameworks two changes would have to be made. First, top customers and suppliers would have to actively participate in the meetings. The interviewed suppliers are interested in the demand management process of the case company (Interview 7). Second, the meetings would have to be event driven. In the case company the forecasters would be willing to update the forecast any time needed, if the system would allow that. (Interview 5, Interview 6) According to the process owner this would add costs but provide little benefits. The case company does not base its production scheduling on forecast. Therefore, it should not invest too much time polishing up the near term forecast numbers.

### 5.1.2 Process integration

Lapide (2005) determines the level of process integration based on how well plans are integrated. The main criterion is the number of participants involved in the shared plan. In the case company, the planning processes are integrated between demand-side and supply-side organizations. The information is shared with each other in Demand Supply Balancing meetings once a month and using e-mail communication. According to the framework the case company is on stage 3 of 4.

Grimson and Pyke (2007) also determine the level of process integration based on how well plans are integrated. The main criterion is the nature of communication. In the case company sales plans primarily drive operations plans. However, some operational information may be used, and plans may be adjusted in response. Head of factory and manufacturing team leaders are responsible for bringing information about capacity constraints. Sourcing and suppliers are responsible of bringing information about material constraints. The framework sets the case company on stage 3 of 5. The average of 15 companies in the study is 2.47. According to the result, S&OP process integration in the case company is slightly above average.

To match the ideal process integration described in these two frameworks three changes would have to be made. First, plans would have to be aligned with the plans of both suppliers and customers. Second, process to develop sales and operations plan would have to be collaborative rather than solely driven by sales. Third, planning process would have to be optimized concurrently for demand and supply to maximize profitability. According to the process owner, at this point of time the case company is not willing to compare different scenarios to maximize profitability.

### 5.1.3 Information technology

Lapide (2005) determines the level of information technology based on the integration level. In the case company, each department uses a spreadsheet to develop their isolated plans. These plans are combined using Excel Visual Basic for Applications macros. The plan is then uploaded into the enterprise resource planning system. The process is sequential. The demand and supply plans cannot be jointly developed. According to the framework the case company is on stage 2 of 4.

Grimson and Pyke (2007) also determine the level of information technology based on the integration level. In the case company the information is centralized in an automated way and then operations planning software is employed. The framework sets the case company on stage 3 of 5. The average of 15 companies in the study is

2.62. According to the result, S&OP technology in the case company is slightly above average.

To match the ideal information technology described in these two frameworks four changes would have to be made. First, demand side and supply-side software applications would have to be integrated, since final demand and supply plans need to be jointly developed. Second, integrated demand-planning technology architecture would have to be used. The interviewed salesperson would be willing to share the information, which is stored in the internal system of sales (Interview 5). Third, the company would have to use revenue and operations optimization software. According to the process owner, at this point of time the case company is not willing to optimize revenue within its S&OP process. Fourth, the company would have to employ real time, integrated solutions that jointly optimize sales decisions, such a pricing, with operations decisions, such as production schedules. At this point of time the case company is not willing to develop different scenarios within its S&OP process.

### 5.1.4 Process improvement

The case company has a wide array of products whose demand is difficult to predict. The company is customer-oriented, because it has relatively few customers and high market share. This makes controlling sales difficult. For these reasons, the company is not willing to develop alternative scenarios and the top-level management is not willing to participate in S&OP. Based on the analysis, the maturity level of the case company's planning process is roughly 60 % in both frameworks.

The planning processes can be improved by extending them to the entire supply chain. Four changes would have to be made. First, top customers and suppliers have to actively participate in the meetings. Second, plans have to be aligned with the plans of both suppliers and customers. Third, demand side and supply-side software applications have to be integrated. Fourth, the process to develop sales and operations plan has to be collaborative rather than solely driven by sales.

## 5.2 Forecasting on product family level using judgmental methods

### 5.2.1 Applicability of the models

In the following chapters I shall apply the frameworks presented in chapter 3.2 to estimate case company's current capability to apply a process where sales provides a forecast on product family level. This is done in the case company for most of the forecasted items. This product family level forecast is split into product level forecast and further into component level forecast. The process is visualized in Figure 19.

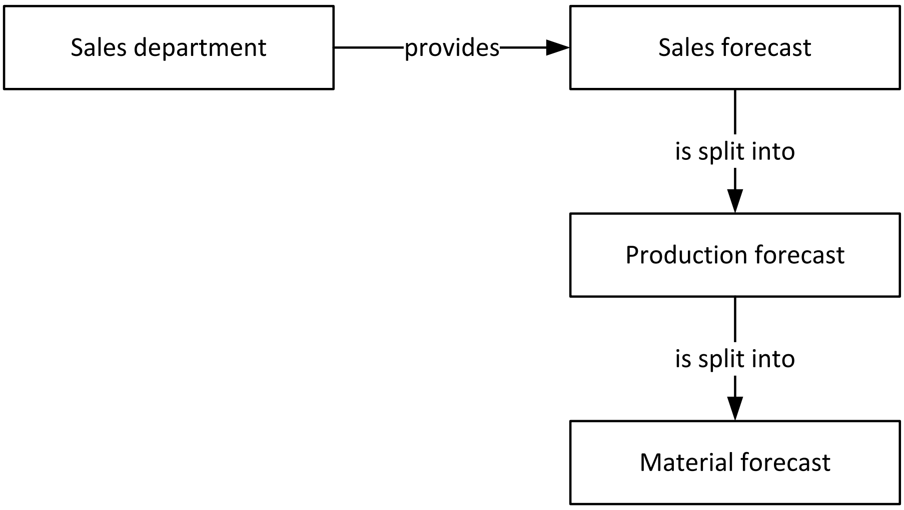


**Figure 19: Forecasting on product family level**

At the moment the case company is not willing to develop alternative scenarios and the top-level management is not willing to participate in S&OP as described in chapter 5.1.4. Therefore, only three of five process steps by Wallace (2006) are applicable. These steps are illustrated in Figure 20.

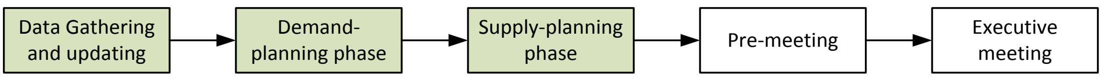


**Figure 20: The applicable S&OP process steps, modified from Wallace (2006)**

### 5.2.2 Data gathering and updating

According to Wallace (2006) “data gathering and updating” phase consists of collection and collation of actual results, generation of the new statistical forecast and so forth. In the case company, these actions are done in the first week of the month. Collection and collation of actual results is done by extracting the data from the ERP system and running an Excel macro. Generation of the new statistical forecast is done using Excel formulas. It is sent to product managers, market segments or sales department depending on the products being forecasted.

According to Lapide (2002) the statistical forecast should be based on unconstrained demand rather than shipment data, because the latter may distort true customer demand if supply constraints have routinely impacted demand. In the case company, shipment data is used to calculate the statistical forecast.

According to Lapide (2004) the statistical forecast forms the working draft from with S&OP participants develop final supply and demand plans. In the case company, the statistical forecast is only calculated for half of the items. The sales department has to provide the input manually for the most important items.

### 5.2.3 Demand-planning phase

According to Wallace (2006) the demand-planning phase consists of forecast updates, new product requirements and creation of consensus forecast approved by the senior sales and marketing executives. In the case company, these actions are done in the second week of the month. An Excel macro is used to generate forecast templates at the desired level or accuracy.  Sales department updates the forecast in the Excel files and sends them back to the head of planning and purchasing. He combines the bottom-up plans and hosts meetings for product managers, market segments or sales department depending on the products being forecasted. An unconstrained sales plan is agreed upon.

According to Lapide (2002) a forecast needs to be aggregated and translated to different participants to look at. For example, marketing and brand managers may need to review it in terms of product groups and brands. It is very important to document the forecast by explaining the assumptions upon which it was created. In the case company the assumptions upon which the forecast was created are documented in the internal systems of sales.

### 5.2.4 Supply-planning phase

According to Wallace (2006) the supply-planning phase consists of the generation of new operations plan that reflects forecast changes and inventory shifts, and the identification of key capacity problems. In the case company, these actions are done in the third and fourth week of the month. In the third week of the month, the product forecast is sent to production planner or to the head of factory depending on the product being forecasted. In the fourth week of the month, the head of planning and purchasing facilitates a supply review meeting. It aims to reach a decision with supply review stakeholders on sales plan constraints. Sales plan confirmation is e-mailed to sales department with the possible constraints.

According to Lapide (2002) the supply plan should also be documented as with the demand plan. In the case company, the assumptions upon which the forecast was created are documented in the minutes of the supply review meeting.

### 5.2.5 Process improvement

Based on the analysis, the current demand management process in the case company is similar to the first three steps of the demand management process by Wallace (2006). These steps are data gathering and updating, demand-planning phase and supply-planning phase.

The process could be improved by generating a statistical forecast for all the forecasted items. This forecast would form a working draft from which the forecasters would develop final demand and supply plans. This statistical forecast should be based on unconstrained demand rather than shipment data because the latter may distort true customer demand if supply constraints have routinely impacted demand.

Furthermore, the documentation practices could be improved. The forecast should be documented by explaining the assumptions upon which it was created. At the moment, the demand forecast is documented in the internal systems of sales. It should be documented in the forecasting system for every participant to look at.

## 5.3 Forecasting on product level using judgmental methods

### 5.3.1 Applicability of the models

In the following chapters I shall apply the frameworks presented in chapter 3.3 to estimate the case company's current capability to apply a process where sales provides a forecast on product level. This is done in the case company for some items. The product level forecast is split into component level forecast. The process is visualized in Figure 21.

In S&OP literature products are called stock keeping units. In the case company a stock keeping unit is a product with a known configuration code. These products are not built until a confirmed order is received. The forecasters would be willing to provide a configuration code for a large potential order (Interview 5, Interview 6).

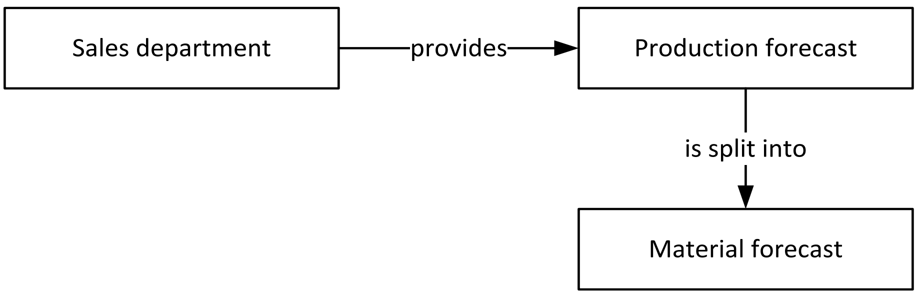


**Figure 21: Forecasting on product level**

### 5.3.2 Organization

According to Singh (2010) a fundamental reason to S&OP failure is the lack of a formally defined S&OP function. The case company has an S&OP function which is called "planning and purchasing". The leader of the function reports directly to the chief operating officer. The prerequisites set by the author are fulfilled.

Bower (2005) lists three threats relating to organizational issues. First threat is that an S&OP leader is responsible of the success of supply and demand planning operations. The leader should be familiar with these operations but not responsible of them. In the case company the head of planning and purchasing is responsible of supply planning operations. Second threat is that the product life cycle meeting is not arranged. In the case company life cycle management unit informs the head of planning and purchasing when products are in ramp up phase. The same unit informs product managers when products are in ramp down phase. However, a separate meeting to review products going through life cycle changes is not arranged. The third threat is that office politics undermine progress. This was not reported in the interviews conducted in the case company.

### 5.3.3 Lack of senior management support

Singh (2010) gives two symptoms of low senior management support. First symptom is that S&OP related issues are relegated to operational levels. They should be on the agenda of the chief financial officer or the chief operating officer. In the case company these roles do not participate in S&OP. Second symptom is that every S&OP discussion does not start and end with financial metrics that are driven by senior management. In the case company, financial metrics are not part of the S&OP process.

According to Bower (2005) the lack of decision making is typical for immature S&OP implementations. At the end of each S&OP review meeting, the facilitator should recap open issues along with the action plans for resolution. This is not done in the case company in the equipment factory. In the system factory meeting minutes are e-mailed to participants.

### 5.3.4 Bottom-up and top-down forecasts in conflict

According to Singh (2010) there is always a mismatch between the bottom-up operational plan and the top-down financial plan. The author has two tools to resolve this conflict. First tool is two-way collaboration that takes into account both plans. In the case company, the top-down financial plan often takes precedence. Second tool is that the sales team provides information on a product level. In the case company, the forecasters mainly provide information on a product family level. However, they would be willing to provide more detailed information of large potential orders (Interview 5, Interview 6).

Bower (2005) lists two threats relating to bottom-up forecast and top-down forecast being in conflict. First threat is a mismatch between S&OP and the corporate strategy. In the case company, the upper management gives growth targets for each region. The forecaster divides these targets into product families when a forecast is created for the equipment factory (Interview 5). The corporate strategy is not explicitly taken into account when a project manager creates the forecast for the system factory (Interview 6). Second threat is that the single number forecast is not reality based. In the case company, the bottom-up forecast and the top-down forecast are sometimes combined by using the average of these two. According to the author S&OP theory suggests the creation of an “unconstrained” single number forecast and then a separate formal process to determine the executability of the forecast.

### 5.3.5 Process improvement

Based on the analysis, the current demand management process of the case company could be improved in four ways. First, the initial forecast could be improved. The forecasters should provide information on product level when it is possible. They should take corporate strategy into account when the forecast is created. Second, the meeting practices could be improved. The task of reviewing products going through life cycle changes should be addressed in a separate portfolio management review meeting. At the end of each meeting, the facilitator should recap open issues along with the action plans for resolution. Third, consolidation of forecasts could be improved. Financial metrics should be part of the S&OP process. However, they should not take precedence. Bottom-up forecast and top-down forecast should be combined by creating an unconstrained single number forecast and then determining the executability of the forecast. Fourth, the organization could be improved. S&OP issues should be on the agenda of the chief operating officer. Head of planning and purchasing should not be responsible of supply and demand planning operations. Alternatively, a separate S&OP planning manager role should be introduced.

## 5.4 Forecasting on component level using statistical methods

### 5.4.1 Applicability of the models

In the fallowing chapters I shall apply the statistical methods presented in chapter 3.4 to estimate the case company’s current capability to provide a forecast on component level. This is done in the case company for components which are sold directly to customers as spare parts. This demand is not modelled in the sales forecast. The process is visualized in Figure 22.


**Figure 22: Forecasting on component level**

### 5.4.2 Moving average

I selected one component which has a large demand. The demand is presented using a blue line Figure 23. I calculated centered moving means using rolling six months period. They are presented using a red line. I used linear interpolation method to fit a curve to these data points.

I used linear extrapolation method to estimate the demand beyond the original observation range. This forecast is presented using a blue line in Figure 24. Actual demand is presented using a red line. The method is not capable of forecasting the decrease in demand at the end of the forecasting period.

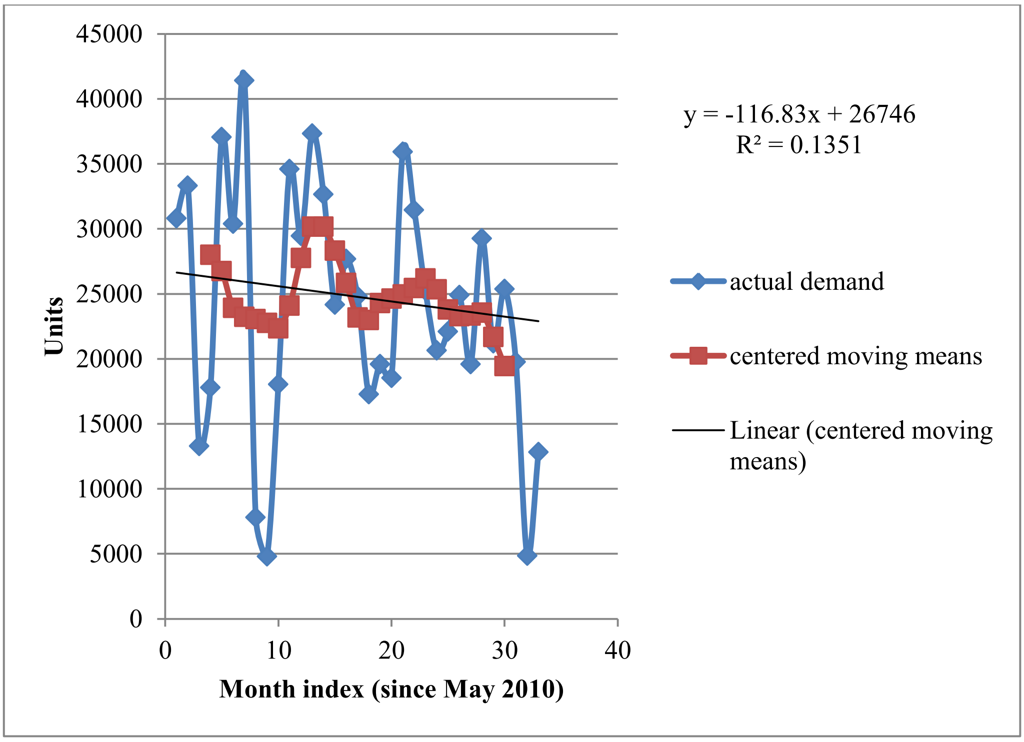


**Figure 23: Modeling demand using moving averaging method**

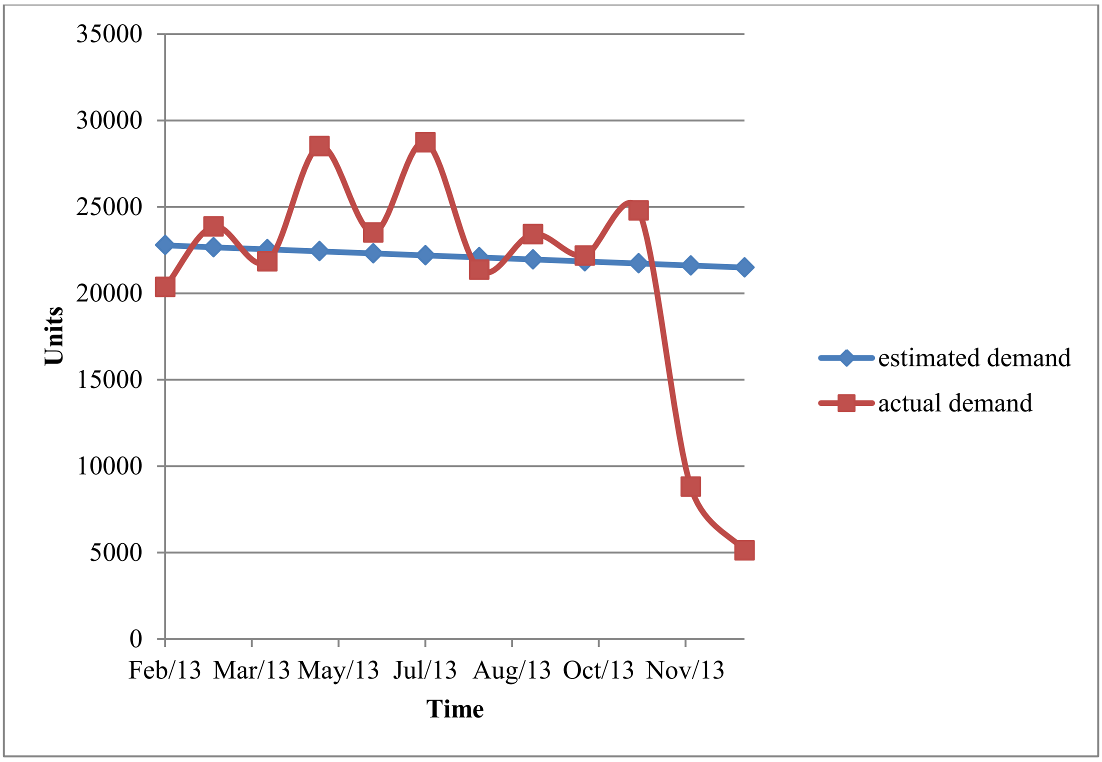


**Figure 24: Predicting demand using moving averaging method**

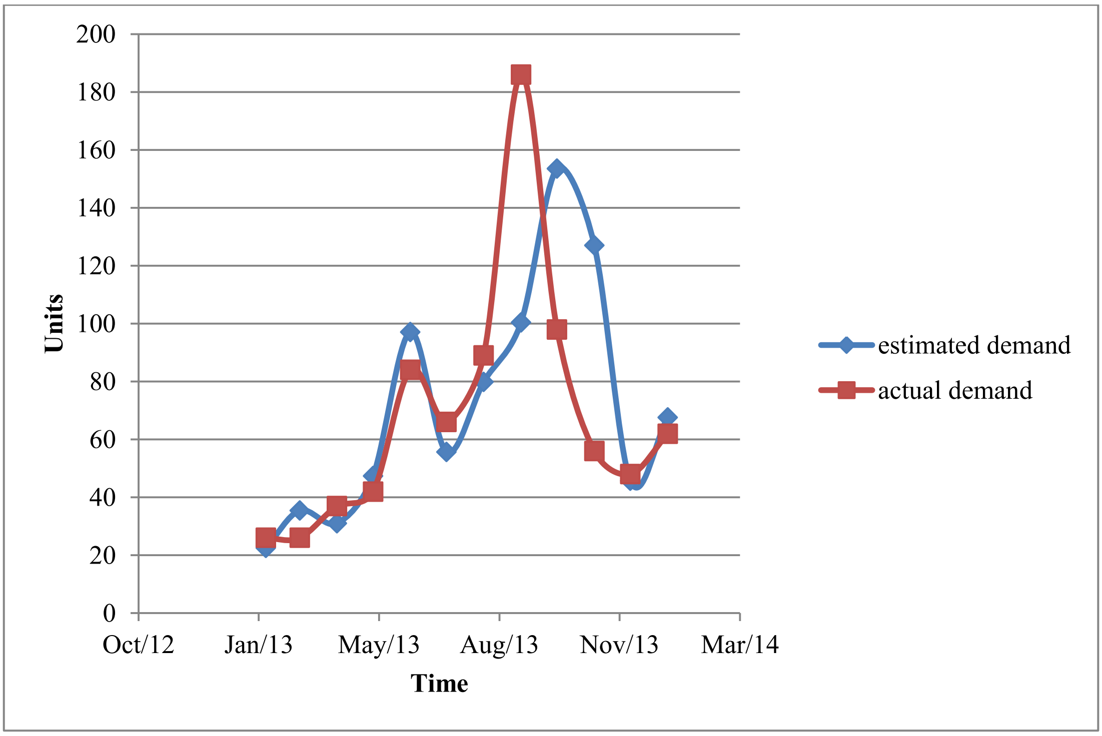


**Figure 25: Predicting demand using decomposition method**

### 5.4.3 Decomposition

I selected a group of components which are used to build a product whose demand is known to have seasonal influences. I calculated centered moving means using rolling twelve months period. I used linear interpolation method to fit a curve to these data points.

I calculated individual seasonal effects by subtracting centered moving means from the original demand data. After that, I calculated average seasonal effects. A baseline forecast was calculated using linear extrapolation method. Average seasonal effect was added to this baseline forecast. The result is shown in Figure 25. The model is capable of forecasting the higher demand in the spring and in the autumn.

### 5.4.4 Comparison of the forecasting methods

I calculated forecasts for 8126 items of the case company using moving average and decomposition methods as described earlier. Consumption data of May 2010–October 2013 was used to predict demand for January 2014–April 2014. These forecasts and the forecast generated by the DSB process were compared to the actual demand.

Symmetric mean absolute percentage error was used to measure forecast accuracy. It is defined as follows:

$$\text{SMAPE} = \frac{1}{n}\sum_{t=1}^{n}\frac{|F_t - A_t|}{A_t + F_t}$$

where $A_t$ is the actual value and $F_t$ is the forecast value. The error rate for each component consists of two parts. First, a SMAPE is calculated for the forecasted four data points. Second, a SMAPE is calculated for the forecasted total volume. The error rate is the average of these two.

I divided the items into three dimensions and compared each method in every dimension. The dimensions are product group, lifecycle phase and importance. Product group has 24 members. The decomposition method could be used for 6 groups which are seasonally influenced. The linear estimate could be used for the rest of the groups.

Lifecycle phases are engineering, ramp up, production, ramp down and history. They are visualized in Figure 26. Statistical methods can be used in the production life cycle phase. Judgement-based methods are better in the other life cycle phases.

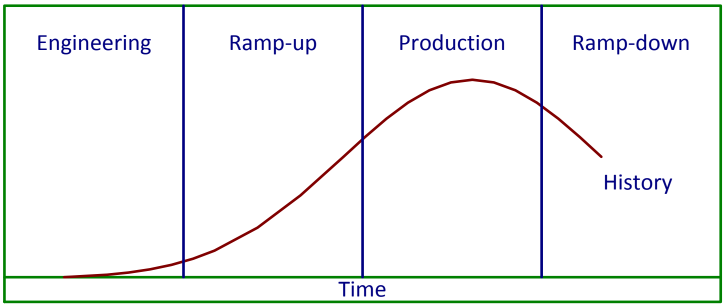


**Figure 26: Product life cycle**

Importance is based on ABC analysis. The inventory items of the case company are grouped into categories based on their relative importance. These categories are presented in Table 5. The statistical methods can be utilized in categories A1–B2. In categories C–XX the number of transactions is too low for accurate forecasting using statistical methods.

**Table 5: Inventory item categorization in the case company**

| Category | Explanation |
|---|---|
| A1 | First 40 % of last 12 months consumption value |
| A2 | Next 35 % of last 12 months consumption value |
| B1 | Next 10 % of last 12 months consumption value |
| B2 | Next 10 % of last 12 months consumption value |
| C | Next 5 % of last 12 months consumption value |
| D | No consumption value during last 12 months |
| RU | Ramp-up items |
| RD | Ramp-down items |
| LTB | Last purchase order done |
| XX | All the rest: configured purchase items, make items, other items not consumed past 12 months and not in the warehouse |

Based on the analysis, a single method cannot be used to forecast every component. This is in line with Chase's (1997) observations. According to him, judgment-based methods are needed, when the sales history is incomplete or there is no distinct pattern in the demand data. According to my observations, statistical methods can be used for items in production life cycle stage. Decomposition methods can be used for these items, if the demand is known to have seasonality. Otherwise, moving average method gives better results.

## 5.5 Proposed future material forecasting in the case company

### 5.5.1 Overview of the process

In an ideal process sales can provide information on product family level or product level depending on what information they have. Statistical methods are used to generate a material forecast for components sold directly as spare parts. Furthermore, the models are utilized to generate a working draft from which the forecasters develop the final demand and supply plans. The process is visualized on high level in Figure 27.

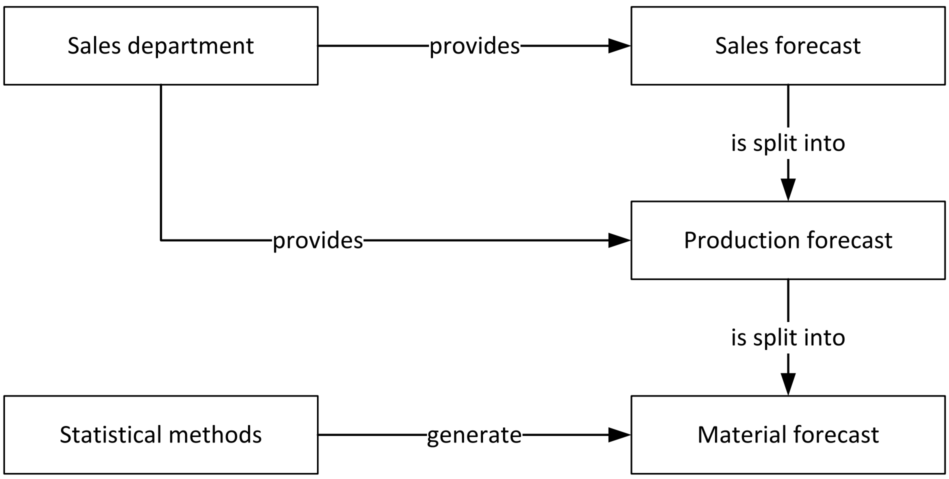


**Figure 27: Proposed material forecasting process on high level**

Sales and operations planning issues are on the agenda of the chief operating officer. Head of planning and purchasing is familiar with supply and demand planning operations. However, he is not responsible of them. Every S&OP discussion starts and ends with a discussion of financial metrics that are driven by senior management. At the end of each meeting, the facilitator recaps open issues along with the action plans for resolution.

### 5.5.2 First week of the month

The process steps are presented in Figure 28. Changes to the current process are presented in green color.

1. Head of planning and purchasing (P&P) holds a portfolio management review meeting with the product life cycle management (LCM). Life cycle statuses are updated to the forecasting system.
2. A statistical forecast is generated for all forecasted items. It is based on unconstrained demand rather than shipment data because the latter may distort true customer demand if supply constraints have routinely impacted demand. The statistical methods are selected based on the nature of demand.
3. Sales department provides a forecast for the equipment factory and product management provides a forecast for the system factory. A configuration code is provided for large potential orders. Sales targets are taken into account when the forecast is created.
4. The assumptions upon which the forecast is created are documented in the forecasting system. Sales department provides the name of the potential customer and its probability when large orders are added to the forecast. Product manager gives the name of the sales opportunity or quote with its probability when a large project is added to the forecast.

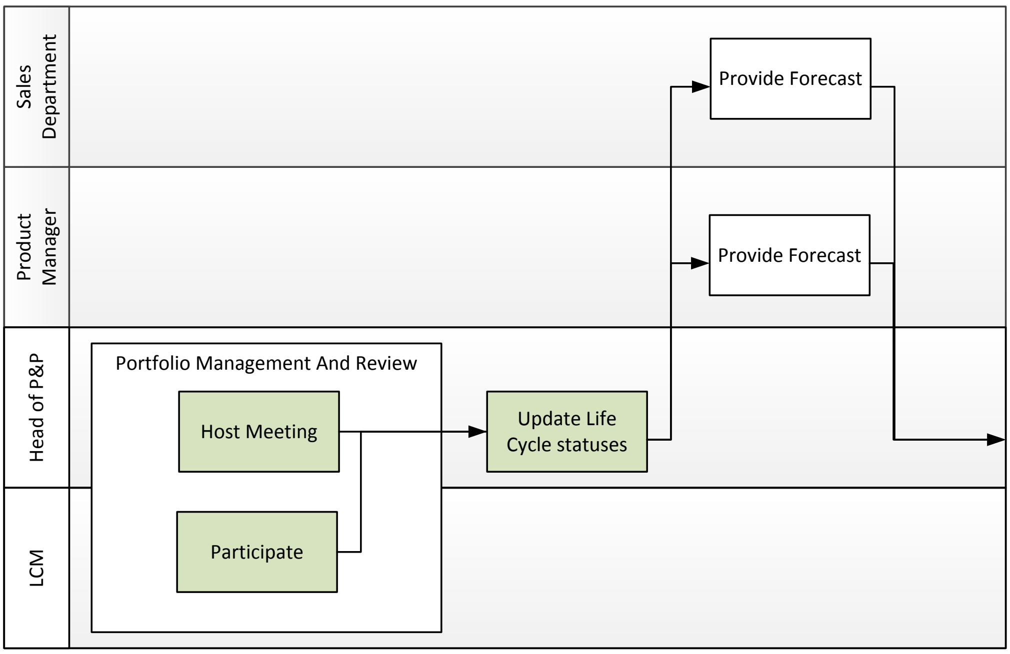


**Figure 28: First week of the demand management process**

### 5.5.3 Second week of the month

The process steps are presented in Figure 29. Changes to the current process are presented in green color.

5. The head of planning and purchasing holds separate demand review meetings for the equipment factory and the system factory. Top customers and lead planners of the factories actively participate in the meetings. At the end of the meeting, the facilitator recaps open issues along with the actions plans for resolution.
6. Process to develop a sales and operations plan is collaborative rather than solely driven by sales. As a result, an unconstrained single number forecast is agreed on.

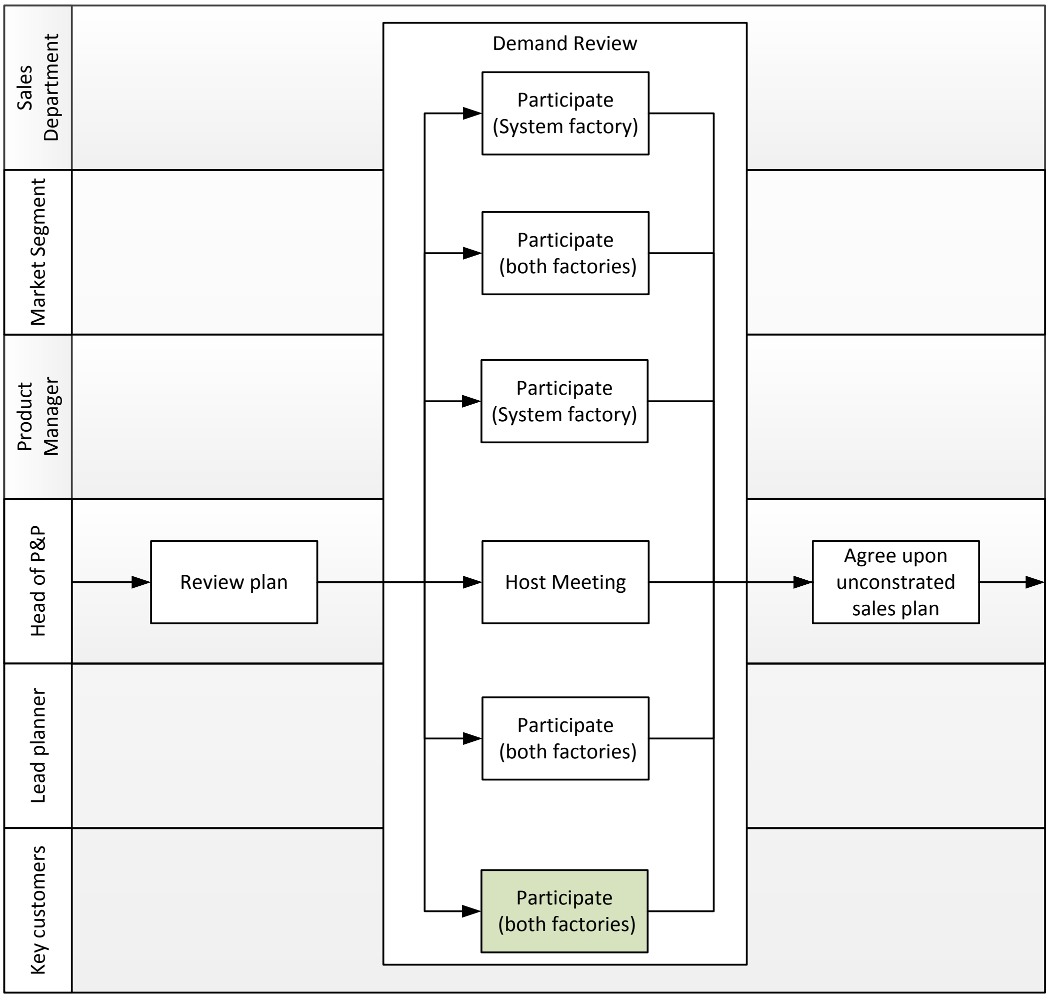


**Figure 29: Second week of the demand management process**

### 5.5.4 Third week of the month

The process steps are presented in Figure 30.

7. A process engineer in the equipment factory and a production planner in the system factory check team and equipment capacity.
8. If the forecast exceeds capacity, they try to organize more capacity.
9. If the forecast does not exceed capacity, they confirm available capacity.
10. Supplier checks supply capability using a global supplier portal.

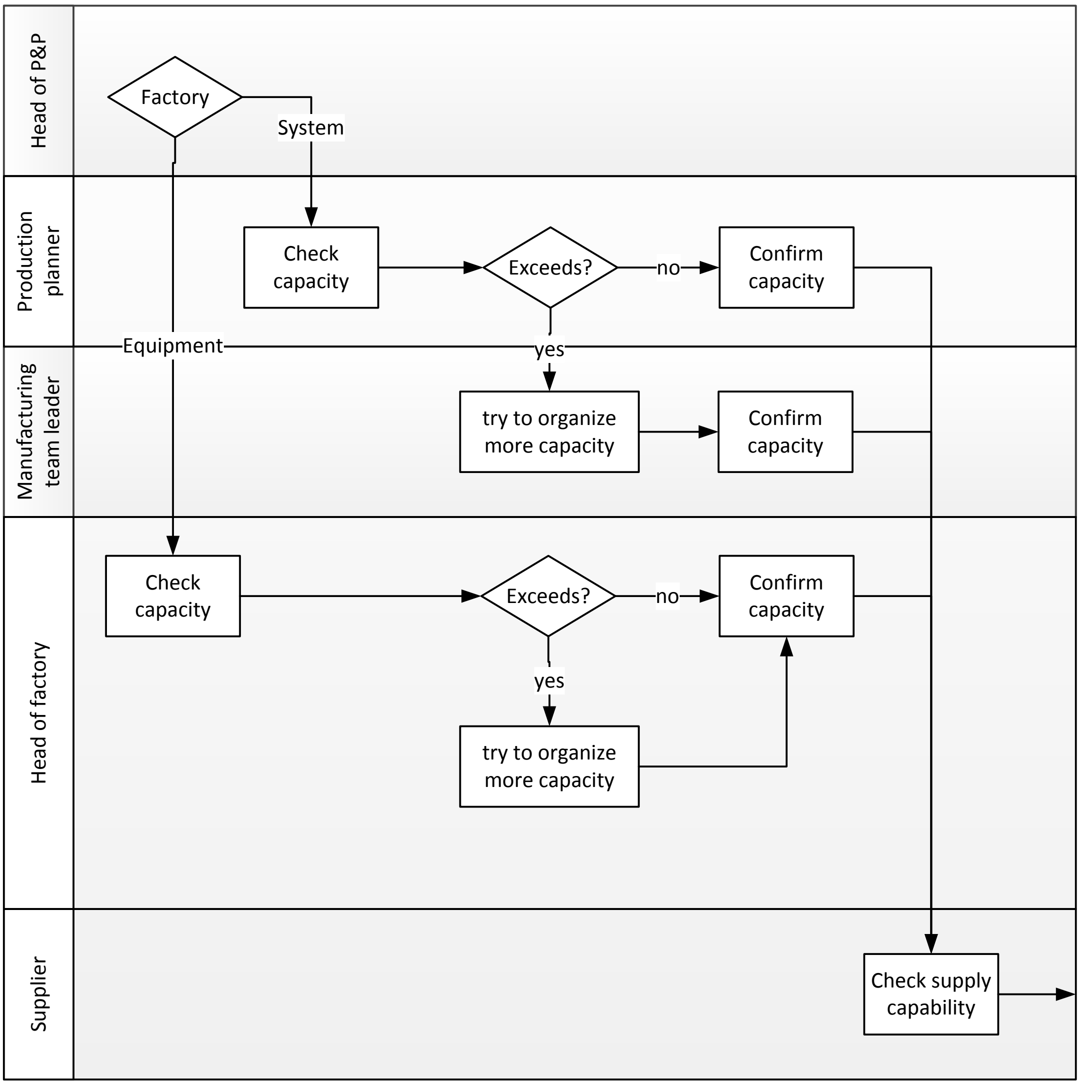


**Figure 30: Third week of the demand management process**

### 5.5.5 Fourth week of the month

The process steps are presented in Figure 31. Changes to the current process are presented in green color.

11. Suppliers confirm supply capability or inform of constraints using a global supplier portal.
12. Sourcing checks material availability and adjusts minimum and maximum inventory parameters for vendor managed inventory (VMI) items. In the case company VMI means that the items in stock are owned by the supplier.
13. Head of planning and purchasing facilitates a supply review meeting. Production planners, manufacturing team leaders and head of factory bring information about capacity constraints. Key suppliers participate in the meeting.
14. Supply review stakeholders reach decision on sales plan constraints. Two-way collaboration is required to take into account bottom-up and top-down plans. Plans are aligned with the plans of both suppliers and customers.

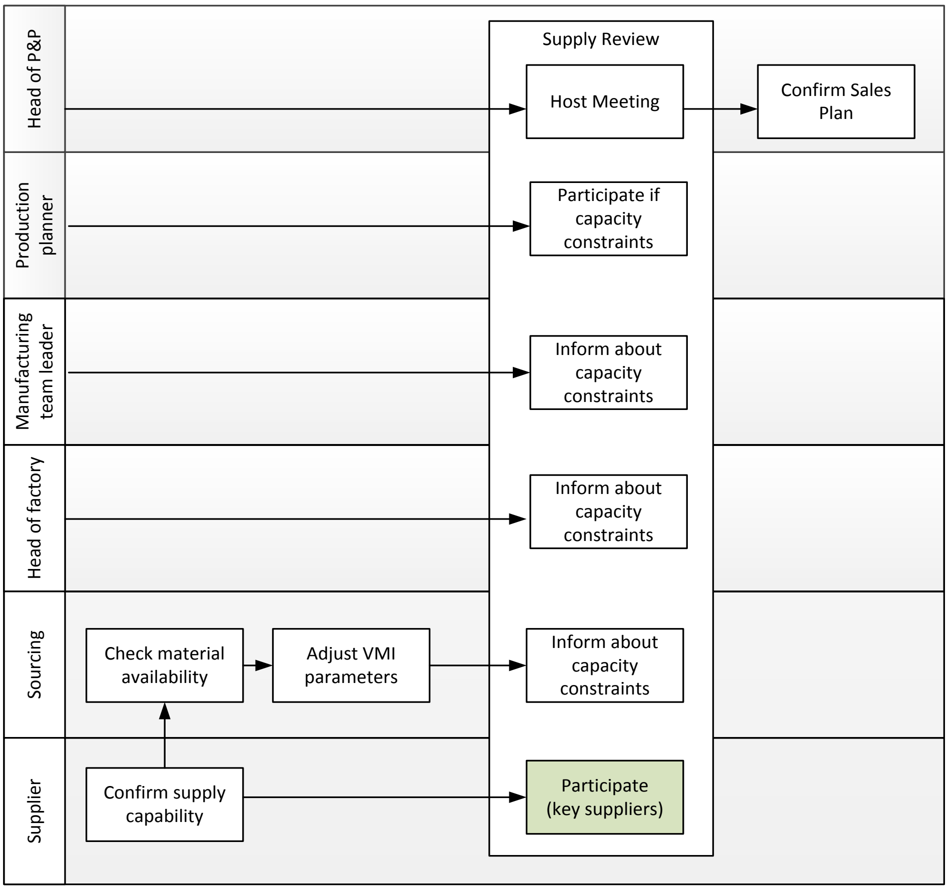


**Figure 31: Fourth week of the demand management process**

## 5.6 Business requirements for the forecasting system

Business requirements for the forecasting system are presented in Table 6. They were derived based on the previous chapters. Demand is predicted on three levels: product family, product and component. The factories use the product level forecast and suppliers use the component level forecast. The system is able to split an aggregated level forecast to lower levels. The process is visualized in Figure 32.

**Table 6: Business requirements of the forecasting system**

| ID | Requirement |
|---|---|
| B1 | Salespersons and product managers shall be able to provide a sales forecast on product family level. |
| B2 | Salespersons and product managers shall be able to provide a product level forecast when this information is available. |
| B3 | The system shall be able to provide a component level forecast using statistical methods. |
| B4 | The system shall be able to generate a production forecast from the sales forecast. |
| B5 | The system shall be able to generate a material forecast from the production forecast. |
| B6 | The system shall allow generating a baseline forecast for every forecasted item using statistical methods. |
| B7 | The system shall allow documenting the forecast by explaining the assumptions upon which it was created. |
| B8 | The system shall allow updating product life cycle changes. |

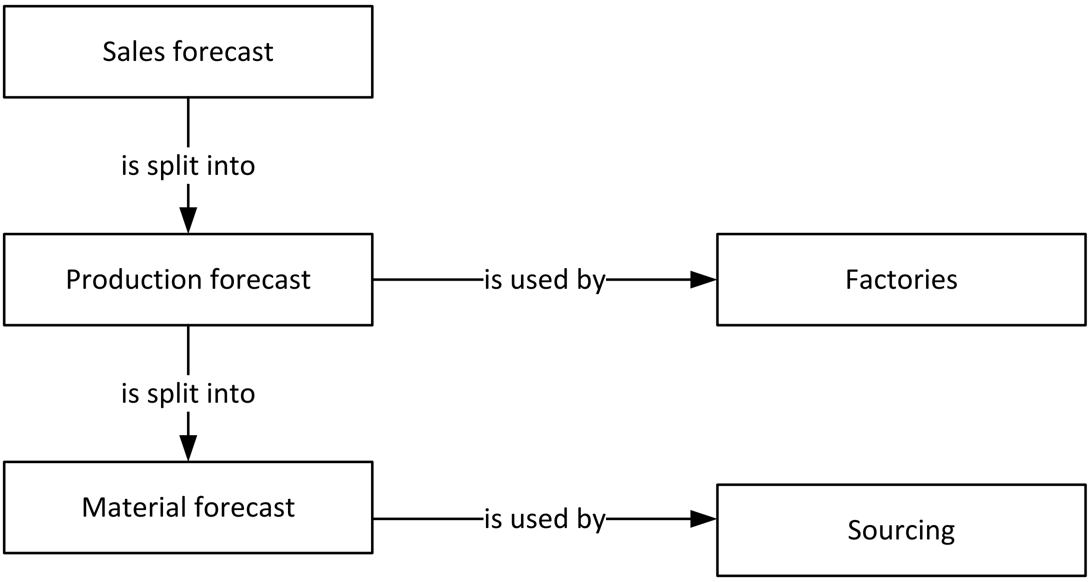


**Figure 32: Material forecasting process on high level**

# 6 Requirements engineering in the case company

## 6.1 Overview of the model

I shall combine the onion model by Alexander and Robertson (2004) and the five step requirements engineering process by Nuseibeh and Easterbrook (2000) to derive user requirements for the tool. The onion model is used to classify stakeholders. The five step requirements engineering process is used to elicit requirements, model and analyze requirements, communicate requirements and agree on requirements. The process is visualized in Figure 33.

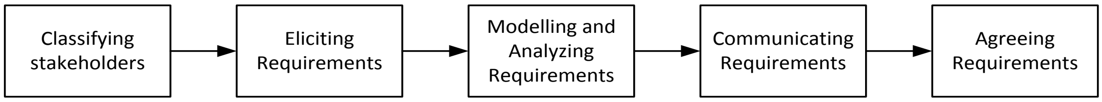


**Figure 33: Requirements engineering in the case company**

## 6.2 Classifying stakeholders

The onion model classifies stakeholders into three categories: our system, containing system and wider environment. The framework was applied in the case company. The result is shown in Figure 34.

Our system is shown in Table 7. Sales representative, product manager, segment director and process specialist give routine commands and monitor outputs from the product. A process specialist is also responsible of maintaining the product and advising other users how to operate it.

**Table 7: Our system in the case company**

| Role | Stakeholder in the case company | Interview |
|---|---|---|
| Normal operator | Sales representative | Interview 5 |
| | Product manager | Interview 6 |
| | Segment Director | |
| | Process Specialist, Planning and Purchasing | |
| Maintenance operator | Process Specialist, Planning and Purchasing | |
| Operational support | Process Specialist, Planning and Purchasing | |

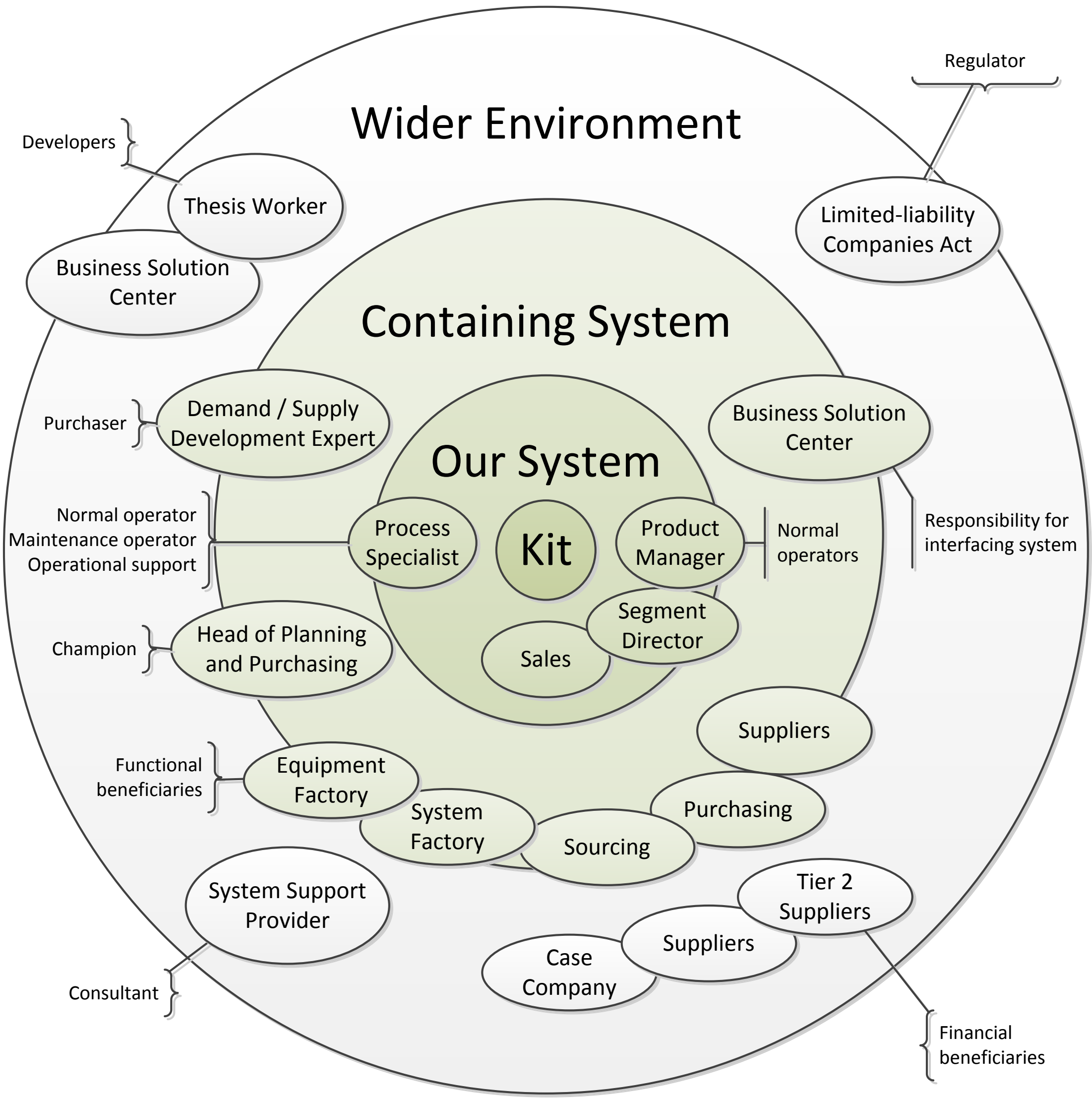


**Figure 34: The onion model applied in the case company**

Containing system is shown in Table 8. Demand/Supply Development Expert is responsible for having the product developed. Head of Planning and Purchasing is responsible for initiating the development of the product, for obtaining funding for it, and for protecting the development from political pressures and funding cuts. Equipment factory, system factory, sourcing, purchasing and suppliers benefit from the results or outputs created by the system. Business Solution Center is responsible of the enterprise resource planning system which has electronic interfaces to the product.

**Table 8: Containing system in the case company**

| Role | Stakeholder in the case company | Interview |
|---|---|---|
| Purchaser | Demand/Supply Development Expert | |
| Champion | Head of Planning and Purchasing | |
| Functional beneficiaries | Equipment Factory | Interview 3 |
| | System Factory | Interview 4 |
| | Sourcing | Interview 1 |
| | Purchasing | Interview 2 |
| | Suppliers | Interview 7 |
| Responsibility for interfacing system | Business Solution Center | |

Wider environment is shown in Table 9. The author is involved directly in development. He is responsible of the requirements specification together with the Business Solution Center. Consultants are used to provide support for the system. The case company and its suppliers benefit financially from the success of the system. The case company is a public listed company. Therefore, it is regulated by Limited-liability Companies Act. For example, all demand information cannot be shared with the suppliers.

**Table 9: The wider environment of the case company**

| Role | Stakeholder in the case company | Interview |
|---|---|---|
| Developers | Thesis Worker | |
| | Business Solution Center | |
| Consultants | System Support Provider | |
| Financial beneficiaries | Case company | |
| | Suppliers | Interview 7 |
| | Tier 2 suppliers | |
| Regulators | Limited-liability Companies Act | |

## 6.3 Eliciting requirements

I interviewed essential stakeholders to get information about the required system. I asked stakeholders questions about the system they currently use and the system to be developed. The interviewed stakeholders are presented in Figure 35. The dates of the interviews are presented in Appendix A. The stakeholders were classified into four categories using two dimensions. The first dimension is operational or managerial level. The second dimension is information producer or information consumer. Information producers provide forecast numbers or check capacity. Information consumers get an estimate of future demand. Each category contains at least one stakeholder. The interview questions are presented in Table 10. The questions from 6 to 8 were further divided into more detailed interview questions. These sub questions are presented in Appendix B. The questions by stakeholder are presented Table 11.

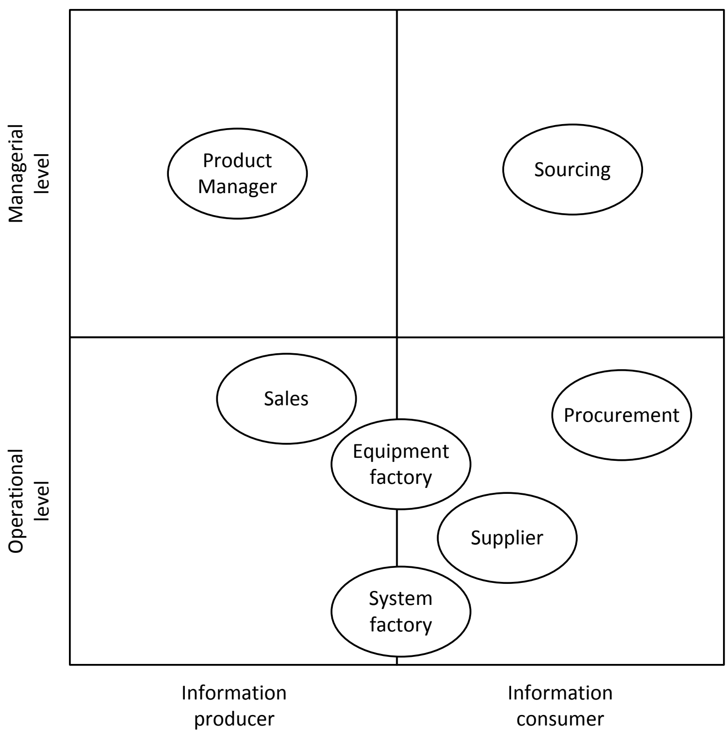


**Figure 35: The interviewed stakeholders**

**Table 10: Interview questions**

| Number | Question | Sub questions |
|---|---|---|
| 1 | How is the forecast currently utilized? | |
| 2 | How would you like to utilize the forecast? | |
| 3 | Why is a global forecast needed? | |
| 4 | How difficult it is to check the available capacity? | |
| 5 | Are the assumptions upon which the forecast is created documented? | |
| 6 | How do you provide the forecast? | Appendix B |
| 7 | How would like to provide the forecast? | Appendix B |
| 8 | How could the accuracy be improved? | Appendix B |
| 9 | What is important when you get the forecast? | |
| 10 | Is it enough for you to see the predicted purchase orders or do you need access to more information? | |

**Table 11: Interview questions by stakeholders**

| Question | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1: Sourcing | ✓ | ✓ | ✓ | | | | | | | |
| 2: Purchasing | ✓ | ✓ | | | | | | | | |
| 3: Equipment factory | ✓ | ✓ | | ✓ | ✓ | | | | | |
| 4: System factory | ✓ | ✓ | | ✓ | ✓ | | | | | |
| 5: Sales | | | | | | ✓ | ✓ | ✓ | | |
| 6: Product manager | | | | | | ✓ | ✓ | ✓ | | |
| 7: Supplier | ✓ | ✓ | | | | | | | ✓ | ✓ |

A use case diagram of the system is presented in Figure 36. The diagram identifies actors involved in the interaction and names the type of interaction. Salespersons, product managers and segment directors use the system to provide a sales plan. Production planners in the system factory and process specialist in the equipment factory use the system to check production capacity. Sourcing and suppliers use the system to check material capacity for confirmed production capacity. If buyers or suppliers notify error in the forecast they contact the head of planning and purchasing. He is responsible of validating the estimate of future demand.


**Figure 36: Use case diagram of the system**

## 6.4 Modelling and analyzing requirements

### 6.4.1 Categories

I took the unconstructed collection of requirements derived from the interviews and organized them into six coherent clusters. The categories are forecaster's view, documenting the forecast, forecast updating frequency, forecast accuracy, forecast coverage and interfacing tools. The categories and their relation to the use case diagram are presented in Figure 37. Forecast accuracy category contains forecast resolution, how the component level forecast should be derived from the product family level forecast and other requirements for accuracy. Forecast coverage category contains the number of items included in the forecast, the number of suppliers the forecast is shared with, the number of countries included in the forecast and the number of parameters shared.

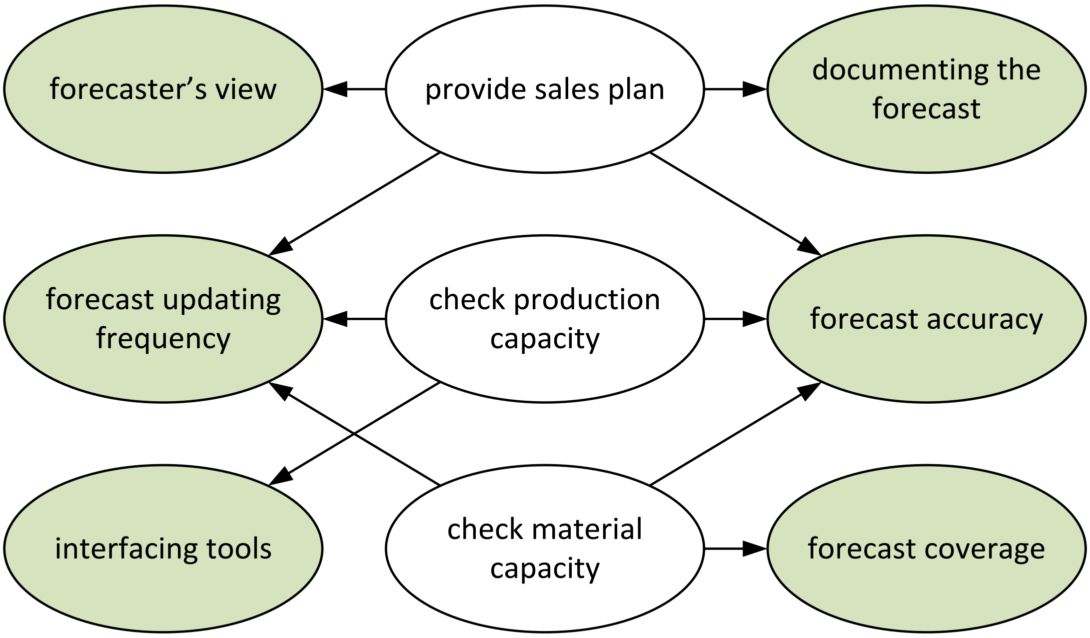


**Figure 37: Classes of interaction divided into six categories**

### 6.4.2 Forecaster's view

Requirements for the forecaster's view were derived by interviewing a sales representative and a project manager. They agreed on requirements. In the current process, sales opportunities and quotes are included in the product manager's view. Sales department would like to have opportunities and quotes included in their view as well (Interview 5).

In the current process, a statistical forecast is calculated for half of the forecasted product families using 12 months of history. Sales department and product managers would like to have a statistical forecast calculated for all forecasted product families. A user would change the values when necessary. (Interview 5, Interview 6) The calculation should be based on a longer period than 12 months of history in the system factory. (Interview 6)

Sales department would like to receive feedback on forecasts. In the current process an error ratio is calculated for each product family. The calculation is based on an Excel formula, which does not give sensible results when a new product family is added to the forecast or an old one is removed. Sales department does not know what level of accuracy is adequate. (Interview 5)

### 6.4.3 Documenting the forecast

Requirements for documenting the forecast were conducted by interviewing a production planner, a sales representative and a project manager. They agreed on requirements. In the current process, a production planner does not know which projects are included in the forecast. This information is sometimes needed when buyers interpret the forecast together with suppliers. (Interview 4) Sales could specify which potential customers are included in the forecast and what are their probabilities. (Interview 5) A project manager could give the name of an opportunity or quote with its probability, when a potential project is added to the forecast (Interview 6).

### 6.4.4 Forecast updating frequency

The participants agreed on the requirements for the forecast updating frequency. In the current process forecast is updated once a month. According to sales, providing a forecast whenever someone wants to change any of the existing plans could be useful. This feature could be utilized if a big case emerges right after the forecast is submitted or if a forecaster makes a mistake in the process. (Interview 5) According to a product manager this feature would be useful when large projects are confirmed (Interview 6).

According to a production planner forecast is not considered when project schedules are decided (Interview 4). According to sourcing, forecast should be updated more often than once a month, if large opportunities suddenly emerge (Interview 1). According to purchasing, updating forecast once a month results in manual work in case of a suddenly received large opportunity. Forecast should be updated more often than once a month, especially for ramp up and ramp down products. (Interview 2) A VMI supplier monitors the forecast every week (Interview 7).

### 6.4.5 Forecast accuracy

Requirements for forecast resolution are in conflict: information consumers would like to have more accurate resolution than information producers. Forecast resolution means how near the forecasted data points are in time dimension. Sales representatives and product managers are information producers. According to the sales department it is not possible to forecast on a more detailed level than monthly level (Interview 5). According to a product manager providing forecast numbers on weekly level would be too often (Interview 6). Equipment factory, system factory, sourcing and purchasing are information consumers. Equipment factory would like to calculate capacity on weekly level (Interview 3). The system factory does not need to have forecast on weekly level (Interview 4). According to sourcing, forecast should have more accurate resolution than the current monthly resolution (Interview 1). According to purchasing, weekly resolution is needed in case of large projects (Interview 2).

The component level forecast can be derived from the product family level forecast by using product variant's frequency of occurrence data and the bill of material data of a single product. According to purchasing, the frequency of occurrence data should be updated more often (Interview 2). Another way to derive the component level forecast is to forecast on product level and use the bill of material data. According to sales, this would result in having too many columns to fill. However, the sales department would be willing to provide detailed configuration of a large potential order if the system would allow that. (Interview 5) According to a product manager, providing forecast on a product level instead of a product family level would result in an increase of workload. It could improve accuracy, if the case company would be willing to invest more time in forecasting. Like the salesperson, the product manager would be willing to provide the detailed configuration of a large potential project. This information is available when a quote is prepared. (Interview 6)

According to a production planner, a more accurate forecast could be shared with team leaders. This would enable a team leader to reserve capacity beforehand. The forecast should be utilized more often. (Interview 4) According to a VMI supplier, the short term forecasts should be more accurate. If the knowledge of buyers and planners would be included in the forecast, the supplier would not have to interpret the forecast together with the case company's buyers before utilizing it. The case company should base its forecast on predicting purchase orders taking yield ratio, buffering and lead times into account. The yield is the percentage of the component that survives the manufacturing process. Buffering means that products are manufactured before the customer order is received. Lead time means the time an item is in production. (Interview 7)

### 6.4.6 Forecast coverage

Forecast coverage category contains the number of items included in the forecast, the number of suppliers the forecast is shared with, the number of countries included in the forecast and the number of parameters shared. The participants agreed on the number of items in the forecast. According to sourcing, forecast should be generated for every purchased item (Interview 1). According to purchasing, a forecast is needed at least for every case company specific component (Inteview 2).

Requirements for the number of suppliers the forecast is shared with were derived by interviewing sourcing and purchasing. Both agree that forecast should be shared with every supplier (Interview 1, Interview 2). According to sourcing, an Excel file can be used if a supplier does not use a global supplier portal (Interview 1). According to purchasing, using Excel to share information is too time-consuming (Interview 2).

Requirements for the number of countries included in the forecast were derived by interviewing sourcing. According to them, all countries should be included. Sourcing is organized globally in the case company. For example, a sourcing manager in Europe should be able to see a material demand estimate for a factory in North America. (Interview 1)

Requirements for the number of parameters shared with the suppliers were derived by interviewing sourcing and a VMI supplier. According to sourcing, more parameters than just estimated forthcoming purchases should be shared with suppliers (Interview 1). According to a supplier, this is needed because the enterprise resource planning system does not work optimally in the case company. If the stock values would be updated immediately when an item is physically removed from a warehouse, a supplier would not need any other information than the predicted purchase orders. (Interview 7).

### 6.4.7 Interfacing tools

Requirements for the interfacing tools were derived by interviewing a process engineer and a product manager. Team capacity is calculated using an Excel tool. The tool has three important limitations. First, it does not provide any graphical illustration of the situation. Second, it does not take into account holidays. Third, team capacity is calculated on monthly level. A weekly resolution would be needed for rolling three months. (Interview 3) Equipment capacity is also calculated using an

Excel tool. The tool does not take into account that same test stations can be used for different products. The parameters of the tool should be updated and more products should be added to the tool. (Interview 3)

Product managers would like to have statistical tools to understand historical demand. With these tools they could better estimate the forthcoming deliveries. At the moment the enterprise resource planning system can be used to review historical demand. However, it does not have any ready-made tools for product managers. They are not willing to create the search queries by themselves. (Interview 6)

## 6.5 Communicating requirements

The requirements for the forecasting system are specified in natural language. I use language consistently to distinguish between mandatory and desirable requirements. Mandatory requirements are written using ‘shall’. Desirable requirements are written using ‘should’. I try to avoid technical software engineering language.

User requirements are prioritized using three classes: must-have (1), useful-to-have (2) and nice-to-have (3). Must-have category contains 10 requirements. They are mainly related to providing a forecast and uploading it to the enterprise resource planning system. Useful-to-have category contains 21 requirements. They are mainly related to analyzing supply constraints. Nice-to-have category contains 10 requirements. They are mainly related to changing the forecast in the middle of the planning cycle and providing more detailed information on upcoming orders. The number of requirements in each priority class is visualized in Figure 38.

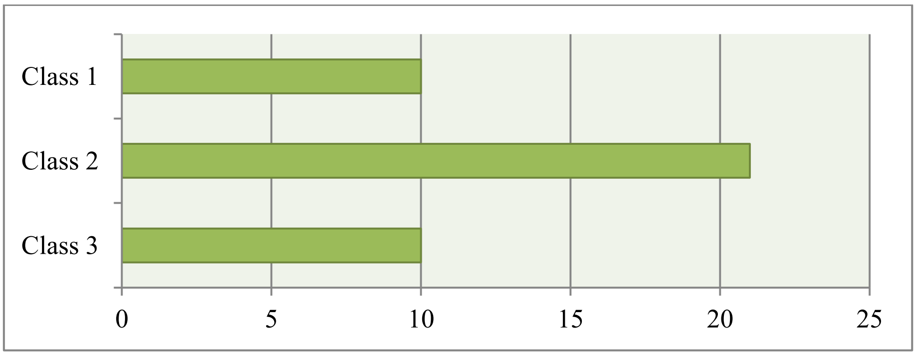


**Figure 38: Requirements by priority**

## 6.6 Agreeing requirements

Requirements were derived by interviewing diverse stakeholders with different needs. This approach may compromise requirements validity, because the stakeholders are allowed to list all their hopes and dreams relating to the system. I tried to avoid this bias by making the proposed set of requirements a compromise across the stakeholder community.

Requirements for the forecast accuracy are in conflict. These requirements are divided into requirements for forecast resolution and requirements for the forecasting level. Information consumers would like to have a more detailed resolution than the information producers. I made the requirements consistent by writing them based on the information producers' views. It makes no sense to ask a forecaster to provide more detailed data than what can be reliably forecasted.

Requirements for forecast updating frequency, forecast accuracy and forecast coverage are interrelated. They all add forecaster's workload. At the same time they increase the amount of information the information consumers can receive. Business requirements B1, B6 and B7 are interrelated with user requirements U1, U20 and U19 respectively.

I compared the requirements document to the case company's process map to make sure that the requirements are complete. I made sure that each process step in the demand management process has a corresponding requirement. Requirements U7–U10 were added after this test. Requirements reviews were arranged to make sure that the requirements are realistic. I went through the list of requirements with a demand–supply development expert, a head of planning and purchasing and an application manager. Obvious mistakes were corrected and phrasing of the requirements was improved.

Verifiability was taken into account by designing test cases for the requirements. The test cases are presented in Appendix C. It was found out that the test cases do not notably differ from the requirements. Therefore, they do not add value to the requirements engineering process. I shall test the requirements by selecting a software product against them in chapter 7.

## 6.7 User requirements for the forecasting system

The requirements are presented in Table 12.

**Table 12: Prioritized requirements**

| ID | Requirement | Priority |
|---|---|---|
| U1 | Salespersons and product managers shall be able to provide a sales forecast. | 1 |
| U2 | The forecasting system shall generate a material demand estimate for every case company specific component. | 1 |
| U3 | Forecast shall include purchased items in all countries. | 1 |
| U4 | Forecasters shall be able to see previous forecast, shipment history, open order back log, sales opportunities and quotes when they fill in the forecast. | 1 |
| U5 | An error ratio shall be calculated for each forecasted item. A forecaster can see development of the error ratio in process of time. | 1 |
| U6 | The process owner shall be able to host a demand review meeting. | 1 |
| U7 | The system shall sum up forecast from different regions for the demand review meeting. | 1 |
| U8 | The system shall show shipment history, open order backlog, previous forecast and previous forecast's accuracy in the demand review meeting. | 1 |
| U9 | The process owner shall be able to correct the forecast together with segment directors in the demand review meeting. | 1 |
| U10 | The system shall allow uploading the forecast to the enterprise resource planning system. | 1 |
| U11 | The forecast shall be provided for the upcoming 12 months. | 2 |
| U12 | The forecast shall be provided using monthly resolution. | 2 |
| U13 | The forecast shall be provided once a month. | 2 |
| U14 | The forecast shall be provided on a product family level. | 2 |
| U15 | Buyers and planners should be able to correct the forecast for the upcoming three months if necessary. | 2 |
| U16 | The forecasting system shall generate a material demand estimate for every purchased component. | 2 |
| U17 | Yield ratio, buffering and lead times should be taken into account when the forecast is generated. The yield is the percentage of the component that survives the manufacturing process. The system takes into account that additional components are needed in if the yield ratio is less than 100 %. Buffering means that products are manufactured before the customer order is received. Lead time means the time an item is in production. | 2 |
| U18 | The system shall allow sharing the forecast with any supplier. | 2 |
| U19 | A forecaster should be able to document the forecast. | 2 |
| U20 | A statistical forecast should be calculated for all forecasted items. | 2 |

| | | |
|---|---|---|
| U21 | A user shall be able to change the values of the statistical forecast when necessary. | 2 |
| U22 | The statistical forecast calculation should be based on several years of history in the system factory. | 2 |
| U23 | The user should be able to choose between several statistical methods. | 2 |
| U24 | Team capacity shall be taken into account before forecast is confirmed. The system shows how much employee hours are needed to manufacture the forecasted amount of products. This figure is compared to the available resources. The forecast can be reduced if needed. | 2 |
| U25 | A process engineer should be able to see a graphical illustration of the workload in teams. Workload means employee hours needed to manufacture the forecasted amount of products divided by the available employee hours. | 2 |
| U26 | The system should take holidays into account when the team capacity is calculated. | 2 |
| U27 | The system should use weekly resolution for rolling three months when the team capacity is calculated. | 2 |
| U28 | Test equipment capacity shall be taken into account before forecast is confirmed. The system shows how much test equipment is needed to manufacture the forecasted amount of products. This figure is compared to the available resources. The forecast can be reduced if needed. | 2 |
| U29 | Test equipment capacity calculation should take into account that a single test station can be used for many products. | 2 |
| U30 | All manufactured products should be included in the test equipment capacity tool. | 2 |
| U31 | The stations each product uses, proportion of station time the product needs and estimated yield should be updated regularly in the test equipment capacity tool. | 2 |
| U32 | Sales persons and product managers should be able to provide a configuration code (or a part of it) for a large potential order. The company has lots of configurable products. In some cases the forecasters can specify the most probable configuration of an upcoming order. The code would be uploaded into the ERP system. The ERP system would calculate the exact material need based on the configuration code. | 3 |
| U33 | Material demand estimate should be updated immediately, when an item is physically removed from the main warehouse. | 3 |
| U34 | The system should allow updating the forecast whenever someone wants to change any of the existing plans. The corrected forecast is sent to supplier. | 3 |
| U35 | A salesperson should be able to correct her forecast if a large case emerges right after the forecast is submitted. | 3 |
| U36 | A salesperson should be able to correct her forecast if a forecaster has made a mistake in the process. | 3 |
| U37 | A product manager should be able to update her forecast if a probability of a large project essentially changes. | 3 |
| U38 | A salesperson should be able to specify which potential customers are included in the forecast. | 3 |
| U39 | A product manager should be able to give the number of the opportunity or quote, when a potential project is added to the forecast. | 3 |
| U40 | A forecaster should be able to upload customer’s forecast to the system. | 3 |
| U41 | A forecaster should be able to see what level of accuracy is adequate. Different thresholds are defined to short-term, medium-term and long-term forecasts. | 3 |

# 7 Selecting a material and production forecasting system

## 7.1 Initial selection process

I developed further the modified PORE by Ottka (2014, p. 37) to select a tool. The process is presented in Figure 39. Four tools were evaluated against the highest priority requirements, any tools that did not meet the requirements were discarded. The process was repeated with descending priorities until only two tools were left. The case company's enterprise resource planning system architecture was taken into account in the tool evaluation phase.

The results of the initial selection process were recorded using a spreadsheet program. Each tool was given its own sheet with a list of requirements, a column for the evaluation result and space for notes. The results were collected into one large matrix.

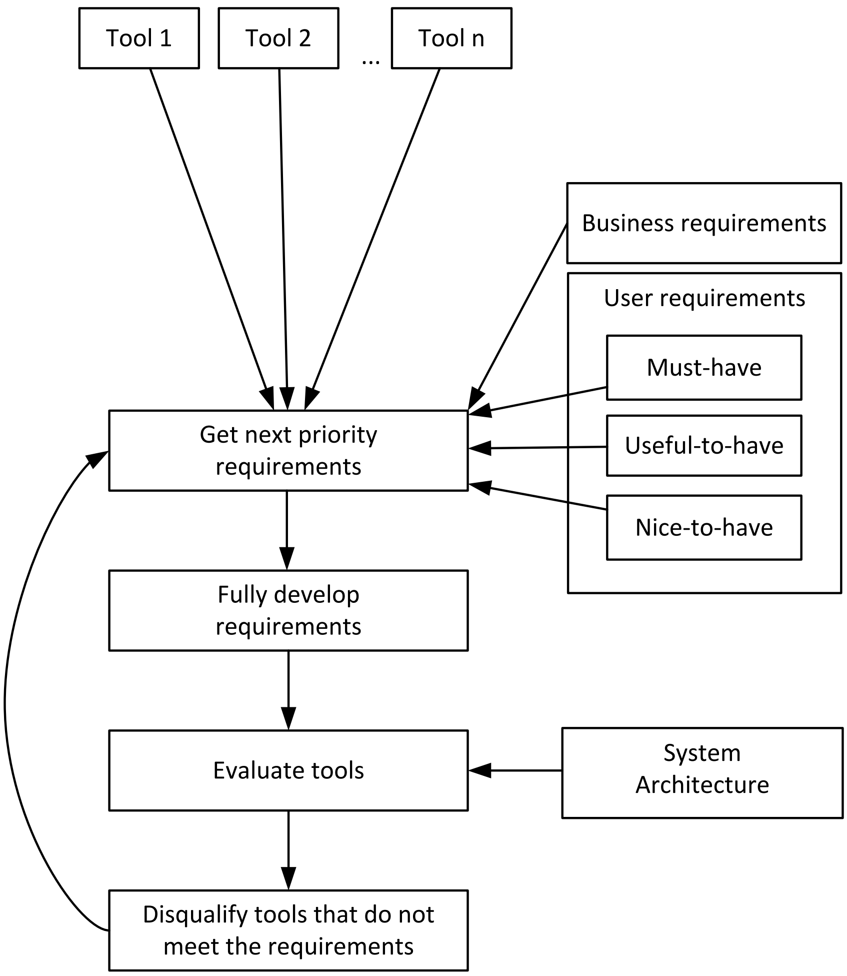


**Figure 39: Initial selection process based on the modified PORE (Ottka 2014, p. 37)**

Four alternatives were included in the analysis. First alternative was to use only statistical models in Excel. Second alternative was to use a combination of statistical and judgmental methods in Excel. These two alternatives were evaluated by estimating the difficulty to implement the tools against the requirements. Third alternative was to use an ERP demand management module. It was evaluated based on its documentation. Fourth alternative was to use a third-party forecasting solution. It was evaluated by using the information available on the vendor's web page and by contacting the software vendor.

## 7.2 Results of the initial selection process

In the first round the tools were evaluated against the business requirements. Using only statistical models in Excel failed the requirements right away. The tool generates a forecast based on the historical component-level demand. Sales persons and product managers are not able to provide a forecast, because these activities would have to be done on a product family or product level. The system is not able split an aggregated level forecast into lower levels. The other three candidates fulfilled all the business requirements. The results are presented in Table 13.

The third-party forecasting solution is marked in parenthesis, because the software vendor does not provide user manuals or other documents describing the features of the system for non-customers. Therefore, I was not able to evaluate whether or not the system meets the requirements of the case company. According to a regional sales director of the software vendor, all the requirements are basic needs and can be managed with the system.

**Table 13: First round of the initial selection process**

| Requirement ID | Only statistical methods in Excel | Hybrid model in Excel | ERP demand management module | Third-party forecasting solution |
|---|---|---|---|---|
| B1 | ✗ | ✓ | ✓ | (✓) |
| B2 | ✗ | ✓ | ✓ | (✓) |
| B3 | ✓ | ✓ | ✓ | (✓) |
| B4 | ✗ | ✓ | ✓ | (✓) |
| B5 | ✗ | ✓ | ✓ | (✓) |
| B6 | ✓ | ✓ | ✓ | (✓) |
| B7 | ✓ | ✓ | ✓ | (✓) |
| B8 | ✓ | ✓ | ✓ | (✓) |

In the second round the remaining tools were evaluated against the must-have user requirements. According to its documentation the ERP demand management module does not have quote information in its database. Therefore, it only partly fulfills requirements U4. Other two candidates fulfilled all the requirements. The results are presented in Table 14.

**Table 14: Second round of the initial selection process**

| Requirement ID | Hybrid model in Excel | ERP demand management module | Third-party forecasting solution |
|---|---|---|---|
| U1 | ✓ | ✓ | (✓) |
| U2 | ✓ | ✓ | (✓) |
| U3 | ✓ | ✓ | (✓) |
| U4 | ✓ | partly | (✓) |
| U5 | ✓ | ✓ | (✓) |
| U6 | ✓ | ✓ | (✓) |
| U7 | ✓ | ✓ | (✓) |
| U8 | ✓ | ✓ | (✓) |
| U9 | ✓ | ✓ | (✓) |
| U10 | ✓ | ✓ | (✓) |

**Table 15: Third round of the initial selection process**

| Requirement ID | Hybrid model in Excel | ERP demand management module | Third-party forecasting solution |
|---|---|---|---|
| U11 | ✓ | ✓ | (✓) |
| U12 | ✓ | ✓ | (✓) |
| U13 | ✓ | ✓ | (✓) |
| U14 | ✓ | ✓ | (✓) |
| U15 | × | ✓ | (✓) |
| U16 | ✓ | ✓ | (✓) |
| U17 | ✓ | ✓ | (✓) |
| U18 | ✓ | ✓ | (✓) |
| U19 | ✓ | ✓ | (✓) |
| U20 | ✓ | ✓ | (✓) |
| U21 | ✓ | ✓ | (✓) |
| U22 | ✓ | ✓ | (✓) |
| U23 | partly | partly | (✓) |
| U24 | ✓ | ✓ | (✓) |
| U25 | ✓ | ✓ | (✓) |
| U26 | ✓ | ✓ | (✓) |
| U27 | ✓ | ✓ | (✓) |
| U28 | ✓ | ✓ | (✓) |
| U29 | partly | ✓ | (✓) |
| U30 | ✓ | ✓ | (✓) |
| U31 | ✓ | ✓ | (✓) |

In the third round the tools were evaluated against the useful-to-have user requirements. Using both statistical and judgemental methods in Excel failed requirement U15. The other two candidates at least partitially fulfilled all the requirements. The results are presented in Table 15.

In the fourth round the tools were evaluated against the nice-to-have requirements. Using both statistical and judgemental methods in Excel failed requirements U34–U37. The ERP demand management module and the third-party forecasting solution platform at least partitially fulfilled all nice-to-have requirements. The results are in Table 16.

**Table 16: Fourth round of the initial selection process**

| Requirement ID | Hybrid model in Excel | ERP demand management module | Third-party forecasting solution |
|---|---|---|---|
| U32 | partly | ✓ | (✓) |
| U33 | ✓ | ✓ | (✓) |
| U34 | × | ✓ | (✓) |
| U35 | × | ✓ | (✓) |
| U36 | × | ✓ | (✓) |
| U37 | × | ✓ | (✓) |
| U38 | ✓ | ✓ | (✓) |
| U39 | partly | partly | (✓) |
| U40 | ✓ | ✓ | (✓) |
| U41 | ✓ | ✓ | (✓) |

## 7.3 Selection results

### 7.3.1 A hybrid model in Excel

A hybrid model in Excel combines statistical and judgmental methods. The system generates statistical forecast for every forecasted product or product family. Sales department and product managers can override the values if necessary. An additional forecast is generated on component level for spare parts. The system meets all the business requirements and the all must-have user requirements.

The system fully meets 18 of 21 useful-to-have user requirements. The system fails to meet requirement U15. Buyers and planners would not be able to correct the forecast for the upcoming three months if necessary. In an Excel-based solution it is difficult to allow a large number of user to participate. The system partly fulfills requirement U23. The users are able to choose between several statistical methods. However a large number methods is difficult to implement in Excel. The system partly fullfils requirement U29. Test equipment capacity calculation takes into account that a single test station can be used by multiple products. However, complex models are difficult to build in Excel.

The system fully meets 4 of 10 nice-to-have requirements. The system fails to meet requirements U34–U37. An Excel-based solution is sequential. Information needs to be downloaded from the ERP system once a month and uploaded back to the system after the modifications have been made. The plan cannot be changed without a new iteration cycle.

The system partly meets requirement U32. Sales person and product managers are able to provide a configuration code of a large potential order. This code can be uploaded to the enterprise resource planning system. However, manual work is needed in the process. The system partly meets requirement U39. A project manager can specify which sales opportunity or quote is added to the forecast. However, the configuration code is not easily derived from this data. Therefore, this practice does not increase forecast accuracy.

### 7.3.2 ERP demand management module

Lansdowne (2010, p. 11) describes the ERP demand management module as a configurable Web-based product to help an organization to perform demand planning and forecasting. The demand management module belongs to the same software suite the case company already uses. Therefore, it would integrate well with enterprise resource planning system of the case company. The sources and destinations of data are presented in Figure 40.

According to Westgate et al. (2009, p. 219) the “ERP components” contain information on shipments, bookings and order backlog. “Supply Chain Intelligence” contains historical production plan and on hand inventory. “Customer Relationship Management” contains the marketing plan. “Inventory Optimization” and “Advanced Supply Chain Planning” contain information on safety stocks. “Legacy system” contains old sales forecasts and customer forecasts.

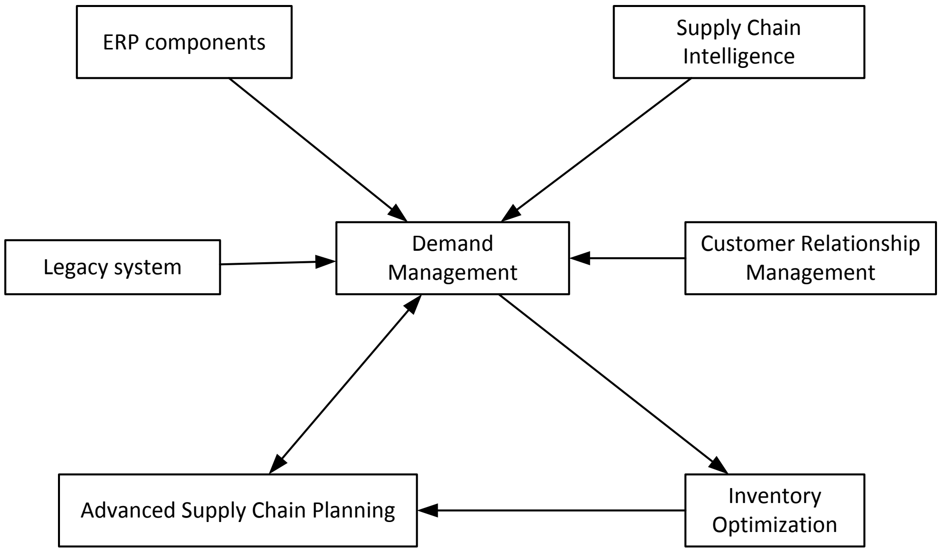


**Figure 40: Demand Management Business Flow (Westgate et al. 2009, p. 219)**

The demand management module meets all the business requirements. It fully meets 9 of 10 must-have user requirements. The system partly meets requirement U4. The forecasters are able to see previous forecast, shipment history, open order back log and sales opportunities when they fill in the forecast. However, quotes are not included in the system.

The system fully meets 20 of 21 useful-to-have user requirements. The system partly meets requirement U23. The demand management module supports multiple statistical forecasting methods. However, the user cannot choose between them. Statistical compexity is hidden from demand planners and managers. The system fully meets 9 of 10 nice-to-have user requirements. The system partly meets requirement U39. A product manager can specify which sales opportunity or quote is added to the forecast. However the system does not take the possibly special configuration into account when the component-level forecast is calculated.

### 7.3.3 Third-party forecasting solution

Viswanathan (2009) describes the third-party forecasting solution as an S&OP solution tailored for the small and mid-size sector. According to him, also subsidiaries of large enterprises can use the plaform. I was not able to critically analyze the features of the product due to the lack of documentation. Therefore, it cannot be equally compared with the other solutions. According the software vendor all requirements can be managed with the system.

The third-party forecasting solution is a Microsoft-oriented application. Therefore, it would have to be customized to integrate with the enterprise resource planning system of the case company. According to the software vendor, the systems can be integrated by exchanging files between them, using a middle database or using service oriented architecture. Exchaning files usually means that manual work is needed when data is updated between the two systems. This makes changing the plan in the middle of the planning cycle a time-consuming process. Thefore, I would recommend investigating the other two altenatives to integrate the systems.

## 7.4 Final recommendations

Based on the initial evaluation commercial off-the-self solutions can be used to generate a material and production forecast for the case company. The ERP demand management module and third-party forecasting solution appear to meet the needs of the case company. I recommend continuing discussions with the providers of these tools. The provider of the third-party forecasting solution did not provide any technical documentation of the system. Therefore, the vendor should be asked to go through the platform with the representatives of the case company.

The forecasting process of the case company cannot be significantly improved using an Excel-based solution. The main reason is that an Excel-based solution cannot be operated by multiple users simultaneously. Another reason is that the commercial solutions have a lot of statistical models built in. Adding the same functionality to an Excel sheet would be very time consuming and therefore expensive.

Based on the results, the requirements derived in this thesis can be utilized when a forecasting system is selected for the case company. The main weakness is that the requirements are mainly functional requirements. They do not specify, for instance, how well the forecasting system should integrate with the enterprise resource planning system of the case company. The requirements of this kind are called quality requirements.. They would differentiate the ERP demand management module from the third-party forecasting solution better than the functional requirements. In the possible future iterations of the action research cycle quality requirements should be taken into account as well.

# 8 Discussion

## 8.1 Material and production forecasting process

*RQ 1: What process can provide an accurate enough material and production forecast for the case company?*

The process proposed in this thesis is based on the five-step S&OP process by Wallace (2006). The first three steps are applicable in the case company: data gathering and updating, demand planning phase and supply-planning phase. The actions are divided into four weeks.

In the first week of the proposal, product life cycle statuses are updated to the forecasting system. A statistical forecast is generated for all items. This forecast is changed when necessary. Sales department provides a forecast for the equipment factory and product management provides a forecast for the system factory. The assumptions upon which the forecast is created are documented in the forecasting system.

In the second week of the proposal, separate demand review meetings for the equipment factory and the system factory are held. Top customers and lead planners actively participate in the meetings. The process to develop sales and operations plan is collaborative rather than solely driven by sales.

In the third week of the proposal, a process engineer in the equipment factory and production planners in the system factory check team and equipment capacity. If the forecast exceeds capacity, they try to organize more capacity. If the forecast does not exceed capacity, they confirm available capacity. The forecast can be modified if needed. Suppliers check supply capacity using a global supplier portal.

In the fourth week of proposal, suppliers confirm supply capability or inform of constraints using a global supplier portal. Sourcing checks material availability and adjusts inventory parameters. A supply review meeting is held. Production planners, manufacturing team leaders and head of factory bring information about capacity constraints. Key suppliers participate in the meeting. Supply review participants reach decision on sales plan constraints.

## 8.2 Requirements for a material and production forecasting system

*RQ 2: What are the requirements of a material and production forecasting system in the case company?*

Requirements of the material and production forecasting system are divided into business requirements and user requirements. Business requirements were derived by analyzing the proposed material forecasting process. Forecasting can be done on a product family level, product level and component level. The factories use the product level forecast and suppliers use the component level forecast. The system is able to split an aggregated level forecast into lower levels.

Critical stakeholders were identified using a stakeholder classification framework by Alexander and Robertson (2004). User requirements were derived using a five-step requirements engineering process by Nuseibeh and Easterbrook (2000). The process consists of eliciting requirements, modelling and analyzing requirements, communicating requirements, agreeing on requirements and evolving requirements. In the first phase ten interview questions were prepared. The questions were presented to seven stakeholders. In the second phase the unconstructed collection of requirements derived from the interviews was organized into six coherent clusters. In the third phase the requirements were documented using natural language. In the fourth phase the requirements were analyzed from the perspectives of validity, consistency, completeness, realism and verifiability. It was found that requirements for forecast updating frequency, forecast accuracy and forecast coverage are interrelated. They all add to the forecaster’s workload. At the same time they increase the amount of information the consumers of the forecast can receive.

User requirements were divided into must-have requirements, useful-to-have requirements and nice-to-have requirements. Must-have requirements are mainly related to providing the forecast and uploading it to the enterprise resource planning system. Useful-to-have requirements are mainly related to analyzing supply constraints. Nice-to-have requirements are mainly related to changing the forecast in the middle of the planning cycle and providing more detailed information on upcoming orders.

## 8.3 Selecting a material and production forecasting system

*RQ 3: How to select a material and production forecasting system for the case company?*

A material and production forecasting system can be selected by using a modified version of the procurement-oriented requirements engineering by Ncube and Maiden (1999). It uses an iterative cycle to narrow down potential candidate systems. Possible tools are evaluated against the highest priority requirements. Any tools that do not meet the requirements are discarded. The process is repeated with descending priorities until only a small number of tools is left.

In this thesis four possible tools were evaluated: using only statistical methods in Excel, using a combination of statistical and judgmental methods in Excel, using an ERP demand management module and using a third-party forecasting-solution. In the first round the tools were evaluated against the business requirements. Using only statistical methods in Excel failed the requirements right away.

In the second round the tools were evaluated against the must-have user requirements. All the three tools at least partially fulfilled all the requirements. In the third round the tools were evaluated against the useful-to-have user requirements. Using both statistical and judgmental methods in Excel failed one of the requirements. In the fourth round the tools were evaluated against the nice-to-have requirements. The remaining two tools at least partially fulfilled all the requirements.

Based on the initial evaluation commercial off-the-self solutions can be used to generate a material and production forecast for the case company. The ERP demand management module and the third-party forecasting solution appear to meet the needs of the case company. I recommend continuing discussions with the providers of these tools. The provider of the third-party forecasting solution does not provide user manuals or other documents describing the features of the system to non-customers. Therefore, the software vendor should be asked to go though the platform with the representatives of the case company.

## 8.4 Threats to validity

A process that can provide an accurate enough material and production forecast for the case company was designed by comparing the current process of the case company to the process descriptions found in literature. I had participated in the sales and operations planning process of the case company since April 2010. Thus, I was familiar with the process. It felt natural to select articles which support the current process. I tried to avoid the bias by reading articles on three categories: forecasting on a product family level, forecasting on a product level and forecasting on a component level. The proposed material forecasting process is a combination of these three.

User requirements for the material and production forecasting system were derived based on interviews. This method carries three risks of bias. First, the researcher might forget important stakeholders. I tried to avoid this bias by classifying stakeholders into categories. I made sure that each category contains at least one stakeholder. Second, the interviewees might be reluctant to discuss controversial topics. This bias is usually avoided by promising the interviewees that individual persons cannot be identified in the final report. I was not familiar with this practice. However, the sales and operations planning process of the case company is not considered controversial. Therefore, the possible impact on results is minor. Third, the stakeholders may list all their hopes and dreams relating to the system. This may result in having too many requirements. I tried to avoid this bias by making the proposed set of requirements a compromise across the stakeholder community.

A process to select a material and production forecasting system for the case company was demonstrated by applying procurement-oriented requirements engineering to four possible tools. Information of the tools had to be acquired in three different ways. This may compromise the validity because these methods are not necessary comparable.

Excel-based solutions were evaluated by estimating the difficulty to implement a solution that would meet the requirements. A possible threat to validity is that it is difficult to predict problems that will arise in the implementation stage. I tried to avoid this bias by utilizing my experience in Excel-based solutions. The problems usually arise when multiple users need to use same tools simultaneously.

The ERP demand management module was evaluated by reading its documentation. A possible threat to validity is that it is impossible to get a deep understanding of a software product without hands-on experience of it. Some features of the system might be difficult to recognize solely based on the user manual. For example, case company specific terms cannot be found in the document. This risk was reduced by the fact that I am somewhat familiar with the phrasing the provider of the ERP system usually uses.

The third-party forecasting solution was evaluated by contacting the software vendor. A possible threat to validity is that a software vendor might exaggerate the features of the product and deprecate the need for modifications. The risk could have been reduced by asking the vendor to go through the platform with the representatives of the case company. However, this platform review was not arranged as a part of this thesis.

## 8.5 Interrelationship between research questions

During writing this thesis it became evident that the research questions are interrelated. The first research question determines a process that provides a sufficiently accurate material and production forecast for the case company. This process description is used to derive business requirements for the forecasting system.

The second research question determines user requirements for the forecasting system. The onion model by Alexander and Robertson (2004) is used to make sure that all relevant stakeholders are included in the analysis. The five-step requirements engineering process by Nuseibeh and Easterbrook (2000) uses the list of stakeholders as an input to create a list of requirements.

The third research question selects a tool. The procurement-oriented requirements engineering process by Ncube and Maiden (1999) uses the prioritized list of requirements derived in the first two research questions as an input. This results in selecting a tool that truly supports the business process.

# 9 Conclusions

The aim of this thesis was to determine how to generate a material and production forecast for a Nordic manufacturing company using software systems. It was found that a modified version of the standard five-step S&OP process can be utilized in the case company. Requirements for a tool supporting the process were derived by analyzing the business process and by interviewing stakeholders. Four possible tools were evaluated against the requirements. It was found that two commercially available tools under study appear to satisfactorily meet the requirements.

The results imply that standard demand management processes and commercially available demand management systems can be utilized in companies which have a wide array of products. This might indicate that customized demand management solutions are not needed. A promising direction of future research would be investigating whether or not this is true for large multi-national companies or companies which have a very complex supply chain.

Furthermore, the results imply that the three-step model used in this thesis to select an information system is applicable to other business processes as well. In the first step the business process is defined. The resulting process description is used to derive business requirements for the system. In the second step user requirements are defined. This is done by identifying relevant stakeholders and applying a requirements engineering process. In the third step an information system is selected. This is done by prioritizing the requirements derived in the first two steps and discarding any systems that do not meet the requirement starting from the highest priority requirements. This results in having only systems that truly support the business process. A promising direction of future research would be trying to apply this model to other business processes.

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## Appendix A: Interviews

Interview 1. March 17, 2014, at 14:00 – 14:30. Case company, Vantaa. Position of interviewee: Senior Sourcing Manager. Semi-Structured Interview.

Interview 2. March 20, 2014, at 13:00 – 13:30. Case company, Vantaa. Position of interviewee: Buyer. Semi-Structured Interview.

Interview 3. March 26, 2014, at 09:00 – 09:30. Case company, Vantaa. Position of interviewee: Process Engineer. Semi-Structured Interview.

Interview 4. March 28, 2014, at 13:00 – 13:30. Case company, Vantaa. Position of interviewee: Production planner. Semi-Structured Interview.

Interview 5. April 3, 2014, at 13:00 – 13:30. Case company, Vantaa. Position of interviewee: Inside Sales Representative. Semi-Structured Interview.

Interview 6. April 9, 2014, at 09:30 – 10:00. Case company, Vantaa. Position of interviewee: Product Manager. Semi-Structured Interview.

Interview 7. April 10, 2014, at 12:00 – 12:30. Case company, Vantaa. Position of interviewee 1: Customer Service Officer–Buyer. Position of interviewee 2: Account Manager. Semi-Structured Interview.

## Appendix B: Detailed interview questions

How do you provide the forecast?

1. Where do the forecast numbers come from?
2. How difficult it is to provide the forecast numbers?
3. What information is needed to provide the forecast?
4. What are the assumptions upon which the forecast is created?
5. Is the corporate strategy explicitly taken into account when the forecast is created?

How would you like to provide the forecast?

6. How would you like to provide the forecast?
7. Would it help to have a statistical forecast calculated for all items instead of just half of the items?
8. What would help you to make better forecast easier?

How the accuracy could be improved?

9. Would you like to provide information on product level instead of product family level?
10. Would it be possible to provide forecast numbers on weekly level?
11. How often would you like to provide the forecast?

## Appendix C: Test cases for the requirements

1. A salesperson provides a forecast for a single product family. The forecast can be seen in the case company's planning tool.
   1.1. A salesperson is required to provide the forecast for the upcoming 12 months.
   1.2. A salesperson is required to provide a forecast using monthly resolution.
   1.3. A salesperson is required to provide a forecast once a month.
   1.4. A salesperson is required to provide a forecast on product family level.
2. A salesperson provides a configuration code of single potential order. The material demand of the potential order can be seen in the case company's planning tool.
3. A planner changes the forecast. This change can be seen in the case company's planning tool.
4. A forecaster provides a forecast for a single product family. The material demand of the forecast can be seen in the case company's planning tool.
   4.1. The material demand for every case company specific component can be seen in the planning tool
   4.2. The material demand for every component can be seen in the planning tool.
   4.3. The material demand for a component needed in a factory in North America can be seen in the tool.
   4.4. A low yield ratio increases the forecast on component level. A small number of subassemblies in the warehouse (less than defined safety stock value) increase the forecast on component level. A long lead time in the case company moves the component level demand to an earlier date.
5. A component is removed from a warehouse. The transaction is entered to the enterprise resource planning system. A supplier sees an increase in the forecast.
6. All suppliers can see predicted purchase orders for the components they deliver.

7. The forecast is changed at an arbitrary moment.
   7.1. A salesperson inserts a large potential order. The new forecast can be seen in the planning tool immediately.
   7.2. A salesperson corrects a previously entered forecast. The modified forecast can be seen in the planning tool immediately.
   7.3. A project manager inserts a new project to the forecast. The new forecast can be seen in the planning tool immediately.
8. A forecaster documents the forecast.
   8.1. A salesperson enters the name of a potential customer when she gives the forecast. A process engineer can see the comment when she checks team and equipment capacity.
   8.2. A project manager enters the name of the quote when she adds a potential project to the forecast. A production planner can see the comment when she checks team and equipment capacity.
9. A forecaster sees shipment history, open order backlog, sales opportunities and quotes when she fills in the forecast. This information is in line with the information in the enterprise resource planning system.
10. A forecaster sees statistical forecast calculated for all forecasted items.
    10.1. A forecaster changes a value and submits. The new value can be seen in the case company’s planning tool.
    10.2. The statistical forecast is based on several years of history. This is validated by making the same calculation in a spreadsheet program.
    10.3. A forecaster changes the statistical method. The new forecast suggestion can be seen in the screen.
11. A forecaster receives feedback on forecast.
    11.1. A forecaster sees an error ratio calculated for each forecasted item. The calculation is validated by making the same calculation in a spreadsheet program.
    11.2. A forecaster can see what level of accuracy is adequate. The limiting values are defined based on feedback from the consumers of the forecast.

12. A salesperson enters a forecast for a single item. A process engineer sees the forecast. She reduces the value. The reduced value can be seen in the case company's planning tool.
    12.1. A process engineer can see a graphical illustration of the workload in teams. The forecast is compared to the maximum workload in a team.
    12.2. A holiday is added to the time and attendance control system of the case company. The maximum workload in a team is reduced.
    12.3. A process engineer sees workload for each team on weekly level for the rolling three months.
13. A salesperson enters a forecast for a single item. A process engineer sees the forecast. She reduces the value. The reduced value can be seen in the case company's planning tool.
    13.1. The forecasted amount is greater than the amount that can be tested using a single test station. The system takes into account that the item can be tested using an alternative test station. The process engineer sees that the test equipment capacity is not exceeded.
    13.2. The list of all manufactured products is compared to the list of items in the test equipment capacity tool. All manufactured products are included in the tool.
    13.3. The case company has a systematic process to regularly update parameters of the equipment capacity tool.
14. Two salespersons enter a forecast for the same product on different regions. The process owner generates a report for the demand review meeting.
    14.1. The process owner sees the sum of the two forecasts.
    14.2. The process owner sees shipment history, open order backlog and previous forecast for the item.
    14.3. The process owner discusses the forecast with the segment directors. She decides to correct the forecast. The correction can be seen in the case company's planning tool.
15. The forecast is uploaded to the case company's enterprise resource planning system. The forecast can be seen in the case company's planning tool.